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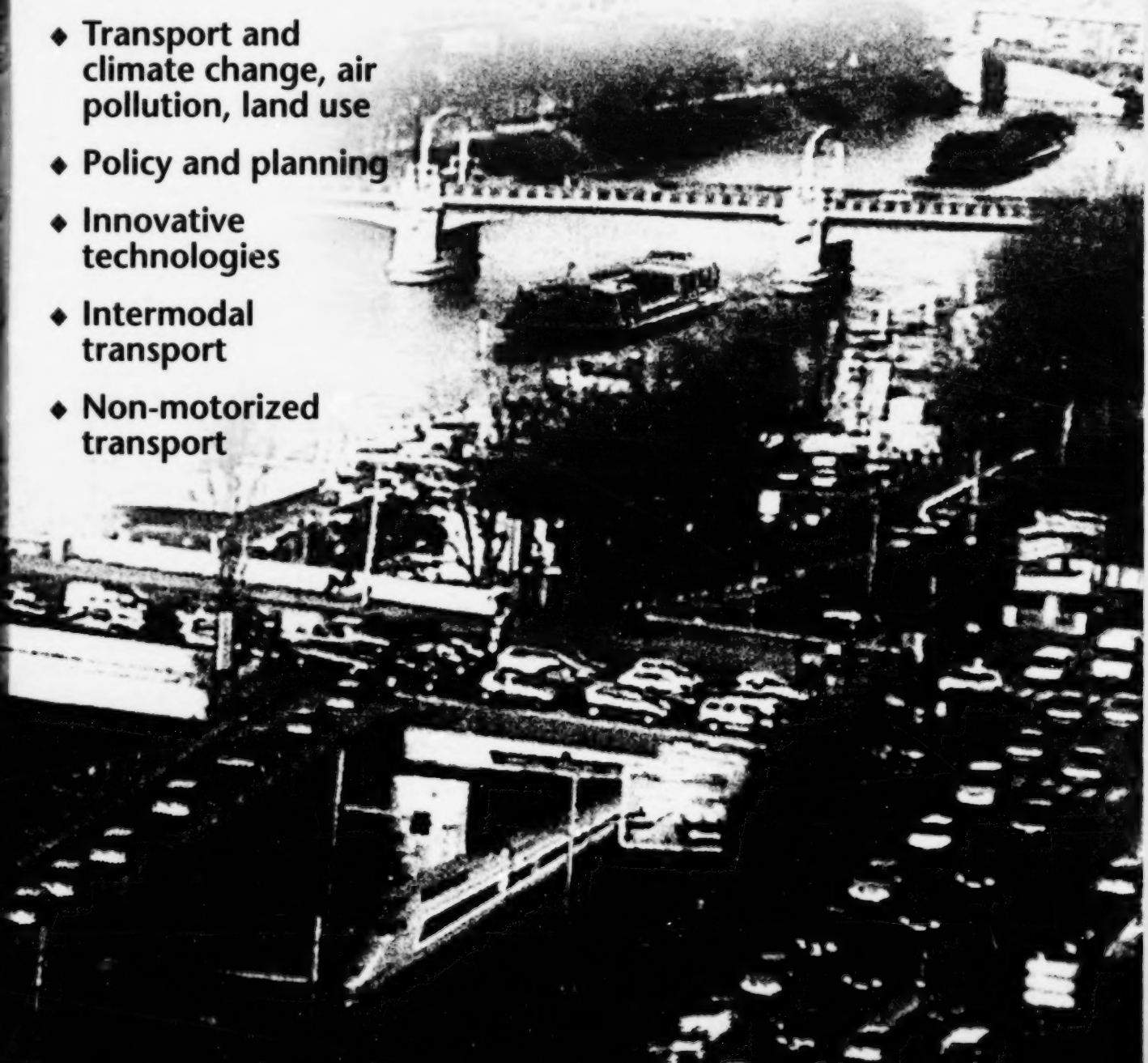
Sustainable mobility

- Transport and climate change, air pollution, land use
- Policy and planning
- Innovative technologies
- Intermodal transport
- Non-motorized transport



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The road to sustainable mobility – time to accelerate

What would the world be like without cars, buses, trucks, trains, airplanes and ships? It would certainly be cleaner (with respect to climate change, local air and noise pollution, and land use), but it would also be a poorer world! Moving people and goods has long been critical to social and economic development.

Today, the turnover (total sales) of the three largest automobile manufacturers exceeds the GNP of the entire African continent. Civil aviation, one of the world's fastest growing industries, has expanded nearly 9% per year since 1960, or 2.4 times average GDP growth. The net profits of all scheduled airlines worldwide were US $8.5 billion in 1997.

The harmful environmental effects of current transport patterns occur at every stage of the life cycle of automotive vehicles, trains, aircraft and vessels. The main impacts are at the operational stage. The transport sector, which currently consumes over 50% of world oil production, is a major source of greenhouse gas emissions, generating one-quarter of total CO_2 emissions.

Transport is responsible for air pollution through emissions of carbon monoxide, particulate matter, volatile organic compounds, lead, sulphur oxides and nitrogen oxides. More than half a million people die prematurely every year due to air pollution closely linked to transport. Noise pollution from transport, especially in major urban areas and around airports, often widely exceeds levels judged tolerable by the World Health Organization.

Automotive transport presents some of the most serious problems worldwide regarding land use. Competition between cars and crops is a major threat to food security in a number of countries. If China reached the same level of car ownership as Japan (there were 23 motor vehicles per 1000 persons in China in 1995, compared with over 550 in Japan), and created roads at an equivalent rate, some 13 million additional hectares would have to be paved. This is the equivalent of half the land used to produce food for its population of 1.2 billion.

Moreover, the increasing demand for new or enlarged airports requires large tracts of land to be taken over, mainly near urban areas.

Transport's environmental impacts are concentrated in megacities. As urbanization increases, so does pressure on urban areas. This situation is especially dramatic in cities in developing countries, where a relatively small amount of space is occupied by the road network (11% in Bangkok, compared to 30% in Los Angeles), separation of working, living and moving spaces needs to be improved, and traffic composition is very mixed. Severe congestion in these cities creates higher pollution levels, to which people in the street are exposed.

Access to both public and private transport is inadequate in developing countries. Existing means of transport are often inefficient as well as highly polluting. Vehicles are generally older than in the developed world. In fact, end of life vehicles in industrialized countries are frequently sent to developing countries without appropriate retrofit or maintenance. Fuel quality in developing countries is often poor. Lead-containing gasoline, for example, causes serious health problems.

In the last few decades efforts have been made to reduce the environmental impacts of transport through technological innovations. These efforts have included more efficient raw materials use, changes in production methods, cleaner fuels, introduction of more fuel-efficient and alternative-fuel engines, and changes in the design of vehicles, aircraft, ships and trains. The concept of recycling of materials has also been developed. Such changes have been promoted through laws, regulations, and better enforcement. Emission standards for various pollutants have sometimes been accompanied by voluntary industry-government agreements.

However, these improvements have largely been outweighed by the increased demand for mobility. Predicted growth in transport activities worldwide will be the major driving force behind the ever-increasing demand for energy. We need to make sure this energy comes from cleaner sources.

Technological innovation should be complemented by complete rethinking and restructuring of transport systems. The focus needs to switch from particular transport modes to the broader question of how to move people, goods, services and information most efficiently. A mix of transport mechanisms, support for non-motorized transport, and changes in land use and infrastructure planning are required, together with different consumption patterns. We must use less polluting transport modes as efficiently as possible, including taking advantage of new mobility concepts like car-sharing and car-pooling, "telecommuting", and avoiding unnecessary travel.

These conclusions are not new. However, if we look at the state of implementation of Agenda 21, UNCED's blueprint for action adopted in 1992, we have to recognize that the problem is more acute than ever. In 2002, the World Summit on Sustainable Development in Johannesburg will take stock of the progress made and outline the remaining challenges. It is time to set concrete targets for addressing these challenges, and to clearly identify ways and means to meet them.

Adequately addressing the highly complex challenges of **sustainable mobility** depends on coordinated action by all stakeholders. Within an enabling policy framework, industry and business are being asked to integrate environmental and social concerns in core decision-making. Continuous dialogue among governments, industry, and environmental and consumer groups can ensure that citizens' needs and rights are taken into consideration, raise public awareness, and help all concerned make informed decisions.

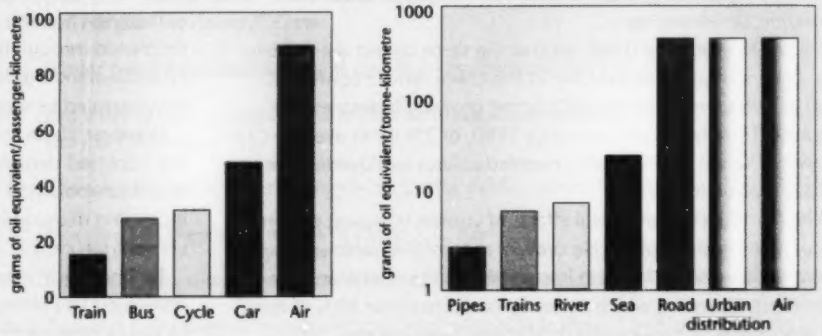
UNEP believes sustainable mobility is crucial if sustainable development is to be achieved. It is therefore working with governments, consumers, NGOs, research institutes, industry and other international entities to raise the awareness of decision-makers in governments and industry, promote integration of sustainability considerations in transport provision and planning, and disseminate examples of best practice. In line with UN Secretary-General's Global Compact, UNEP is also working jointly with major automotive manufacturers and other stakeholders to identify possible solutions through its Mobility Forum.

In this issue of *Industry and Environment* we present some examples of policy measures, voluntary agreements, design advances, and other initiatives that are successfully contributing to sustainable mobility. ◆

Sustainable mobility: facts and figures

Access to goods, services and information is essential for economic and social development, as well as for quality of life. Transport, in all its many forms, provides both *access* and *personal mobility*. It plays an essential role in the economies of all countries – industrialized and developing. It is of critical importance for virtually all industries and activities. The value added represented by transport is estimated at 3-5% of global GDP; transport directly provides 5-8% of a "typical" country's total paid employment.[1] Indirect value-added and employment in related sectors (e.g. the automotive industry) are much higher. However, transportation activities contribute to a range of environmental problems that affect air, land, water, ecosystems and human health. Preventing and mitigating these problems is a major sustainable development challenge.

Figure 1
Energy consumption by transport mode



Source: INRETS (Institut National de Recherche sur l'Environnement, les Transport et la Sécurité)

Increased urbanization has led to greater demand for mobility worldwide. Transport demand has been exploding, in large part due to population growth, rising incomes and living standards, increased world trade, and evolving industrial practices. In most developing and transition countries, demand for freight and passenger transport is growing 1.5 to two times faster than GDP. Most of this increase concerns road transport.[2] Countries' dominant transport types and patterns are relatively slow to change, however, especially in the industrialized world. This reflects the scale of infrastructure and capital investment required.

A country's transportation system has historically been a good indicator of its level of economic development. **Table 1** shows freight and passenger totals for major mechanized transport modes in selected OECD countries. In many countries in the developing world, people still mainly walk or bicycle, while goods are transported using animal power. Only 30% of roads in developing countries were paved in 1996, compared with over 90% in the high-income countries. Although modern forms of transportation have grown rapidly in some developing countries (e.g. China and India), even higher rates of population growth mean these countries will probably still have very limited transportation services in 2020 if evaluated according to industrialized countries' standards.[3]

Transport modes: energy consumption and environmental impacts

The major environmental effects of transport arise from use of energy and other resources, air emissions, and the need for land and infrastructure (**Table 2**). Of these, impacts related to fossil fuels are the most severe and have the widest-ranging

Table 1
Freight and passenger totals for major mechanized transport modes in selected OECD countries

Transport, 1998

	Freight transport billion tonne-kilometres						Passenger transport billion passenger-kilometres					Road accidents		
	Rail	Roads	Inland waterways	Pipelines	Total inland freight	Coastal shipping	Rail	Buses and coaches	Private cars	Total road transport	Total passengers	Accidents involving injury thousands	Killed & injured thousands	Killed per 100,000 of population
Australia	357.0 a	114.85 a	46.6 a	..	..	112.7	9.4 a	16.4 a	217.4 a	233.8 a	243.2 a	..	..	9
Czech Republic	18.8	33.9	0.8	2.1	55.6	-	7.0	8.7	60.8	69.5	76.5	27.2	36.6	13
France	52.6	167.8	6.5	21.6	248.5	6.3 b	64.6	42.5	706.3	748.8	813.4	124.4	177.0	15
Greece	0.3	13.2	-	-	13.5	..	1.6	5.9	32.1	38.0	39.5	24.8	35.6	21
Italy	24.7	213.5	0.2	18.2	256.6	39.9	47.3	90.9	643.7	734.5	781.8	204.6	299.7	11
Japan	22.9	306.3 b	220.0 c	..	..	218.8	388.9	95.0 c	684.0 c	779.0 c	1334.0 c	803.9	999.9	9
Korea	13.9 a	57.7 c	66.2 c	..	..	..	42.6 c	65.4 c	72.2 c	137.6 c	180.2 c	239.7	349.6	23
Mexico	40.3 c	165.0 c	..	..	..	..	88.0 c	0.4 c	..	..	..	..	..	..
Spain	11.8	228.6	-	6.9	247.3	32.3	18.9	49.4	296.6	3461	364.9	97.6	147.3	15
Sweden	19.0	32.7	-	-	51.7	8.4 b	7.0	9.4 b	93.6 c	103.0 b	109.8 b	15.5	21.9	6
Turkey	8.5	135.3	-	39.7	183.4	36.2 a	6.1	..	..	166.7	172.8	63.3	120.3	10
United States	1979.7 c	1439.5 c	518.5 c	904.0 c	4841.7 c	595.8 c	42.1 c	222.9 c	3756.2 c	3979.1 b	4021.2 b	2455.1 b	3441.1 b	16 b

Notes:
.. Not available - Not applicable a 1993 b 1997 c 1996 d 1994

Source: OECD, 1999

Table 2
Selcted environmental effects of principal transport modes

Principal transport	Air	Water resources	Land resources	Solid waste	Noise	Risk of accidents	Other impacts
Marine and inland water transport		Discharge of ballast water, oil spills, etc.; modification of water systems during port construction and canal cutting and dredging	Land taken for infrastructure; dereliction of obsolete port facilities and canals	Vessles and craft withdrawn from service		Bulk transport of fuels and hazardous substances	
Rail transport			Land taken for rights of way and terminals; dereliction of obsolete facilities.	Abandoned lines, equipment and rolling stock	Noise and vibration around terminals and along railway lines	Derailment or collision of freight trains carrying hazardous substances	Partition or destruction of neighbourhoods, famland and wildlife habitats
Road transport	Air pollution (CO, HC, NO_x, particulates and fuel additives such as lead); global pollution (CO_2, CFCs)	Pollution of surface water and groundwater by surface run-off; modification of water systems by road building	Land taken for infrastructure; extraction of road building materials	Abandoned spoil tips and rubble from road works; road vehicles withdrawn from service; waste oil	Noise and vibration from cars, motorcycles and lorries in cities and along main roads	Deaths, injuries and property damage from road accidents; risks of transport of hazardous substances; risks of structural failure in old or worn road facilities	Partition or destruction of neighbourhoods, famland and wildlife habitats; congestion
Air transport	Air pollution	Modification of water tables, river courses and field drainage in airport construction	Land taken for infrastructure; dereliction of obsolete facilities	Aircraft withdrawn from service	Noise around airports	Deaths, injuries and property damage from aircraft accidents, but slight compared with road transport	

Source: The World Environment 1972-1992: Two Decades of Challenge, Chapman and Hall, 1992

effects. The energy intensity of various transport modes (i.e. the amount of energy required to transport a passenger or unit of freight) is a key factor in determining transport related environmental impacts. **Figure 1** shows the relative energy intensity of some types of passenger and freight transport.

Tables 3 and 4 show world transportation energy demand by mode and by region. Transportation energy accounts for about half of world oil demand, and road vehicles maintain a dominant share (over 70%) of transportation energy use. Since 1970, transportation energy demand has grown by 110% or 18 million barrels of oil per day. The US Department of Energy projects that it will grow another 77%, or 27 million barrels per day, by 2020. On a percentage basis, the increase in transportation energy consumption is expected to rise at over twice the projected rate of world population growth. Growth in oil consumption is directly related to rising air emissions (see below).

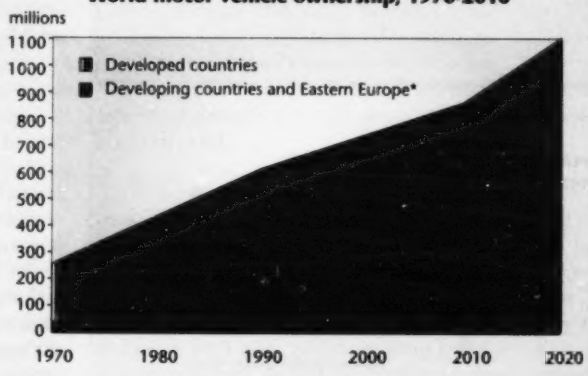
Developing countries account for 55% of projected growth in transportation energy demand. Even in the most economically advanced countries, however, transportation energy use per capita is expected to continue to increase when people operate sport utility vehicles (SUVs) and other large cars, and where larger incomes allow them to travel more frequently by air on long-distance vacations.

Freight transport is an especially important element in transport energy impacts, accounting for one-third of total transport energy demand in OECD countries[4] and some 43% of the world's total transport energy consumption.[5] Changing production methods, including "just in time" delivery of parts and supplies in manufacturing, contribute to ever-increasing demand for freight transport. Most of the growth is in road freight. While overall freight transport has increased by an average of 2-3% annually in OECD countries since the 1970s, road freight has increased by an average of 3.7% annually. Although complete figures for developing countries are not available, the World Energy Council estimates that growth in truck transport between 1995 and 2020 will be 3-4% in Asia and almost 5% in Sub-Saharan Africa.

Air freight has expanded rapidly in recent years (up to 10% annually in some countries), and is expected to continue to grow even faster than road transport. It currently accounts for less than 2% of all freight in OECD countries, but by 2020 it is projected to have a 5% share and to make up 45% of the anticipated increase in aviation fuel demand. Only 20% of the world's commercial aircraft fleet are dedicated freight planes. However, freight is often transported in extra space on passenger planes, making it difficult to determine the energy intensity of air freight transport. The OECD estimates that by 2020 air freight will consume four to six times as much energy per tonne-kilometre as road transport, contributing to overall growth in freight transport's energy intensity.

Rail transportation, inland water shipping, ocean shipping, and pipelines are expected to account for a decreasing share of world transportation energy use as road (including freight trucks) and air transportation expand. Combined, these modes are expected to use 12% of transportation energy in 2020, down from 17% in 1996 and 22% in 1980. But declining shares of transportation energy consumption do not mean that these transport modes are declining in either the volume or the value of the freight they move, or in the total amount of energy they consume. Worldwide, energy use for these other forms of transportation is projected to increase from 5.1 million barrels of oil per day in 1996 to 6.5 million barrels per day in 2020.[6]

Figure 2
World motor vehicle ownership, 1970-2010



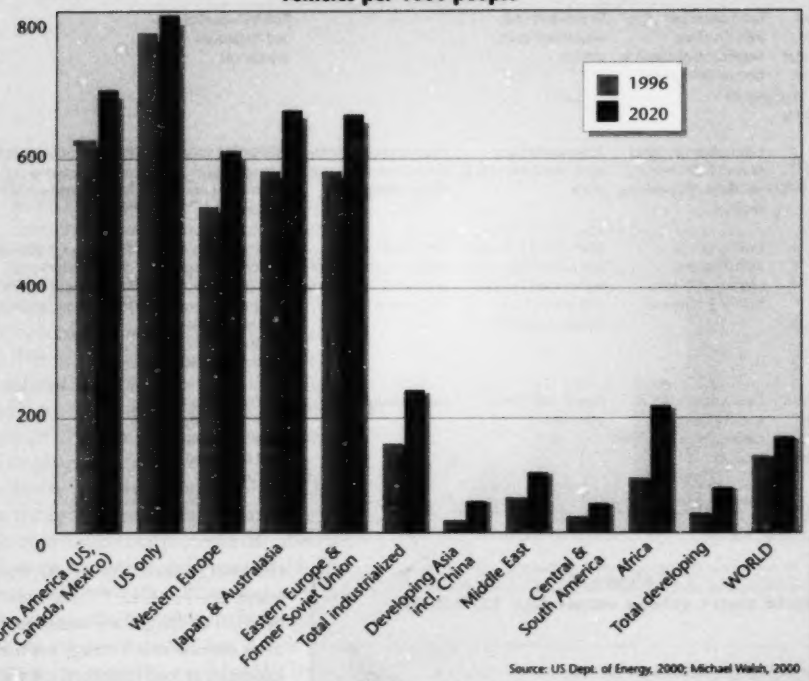
* Note: Eastern Europe includes the former Eastern bloc countries except East Germany

Source: Asif Faiz and Surhid P. Gautam, "Motorization, urbanization and air pollution," discussion paper (The World Bank, Washington, D.C., September 1994), p. 8; US Dept. of Energy

Motor vehicles

Motor vehicles (cars, trucks, buses and motorcycles) are by far the most important form of transport in terms of intensity of use and environmental impacts. While all forms of motorized transportation are on the increase, transport is growing at the fastest rate, especially in developing countries. The total number of vehicles is rising rapidly, as shown in **Figure 2**, and is expected to pass 1.1 billion by 2020.[7] Vehicles per capita figures vary widely in different parts of the world, but they will more than double by 2020 (**Figure 3**). The growth in road transport is the main reason that transport related oil consumption is projected to increase from about 35 million barrels per day in 1996 to

Figure 3
World vehicle ownership by region 1996-2020



Source: US Dept. of Energy, 2000; Michael Walsh, 2000

Table 3
Regional transportation energy demand by mode: million tonnes of oil equivalent (Mtoe)

Western Europe (WEU)

	LDV	Air	Truck	Rail*	Total
1995	197	37	71	7	312
2020	205	90	109	8	413
Change	8	53	38	1	101
Growth (%)	0.2	3.6	1.7	0.8	1.1

OECD Pacific (PAO)

	LDV	Air	Truck	Rail*	Total
1995	86	13	37	2	137
2020	92	35	74	3	201
Change	5	22	36	1	64
Growth (%)	0.2	4.0	2.7	1.5	1.5

Central and Eastern Europe (EEU)

	LDV	Air	Truck	Rail*	Total
1995	21	0	13	3	37
2020	39	0	15	1	54
Change	18	0	1	-1	18
Growth (%)	2.5		0.4	-3.5	1.6

Sub-Saharan Africa (AFR)

	LDV	Air	Truck	Rail*	Total
1995	17	3	12	3	35
2020	22	9	40	3	74
Change	6	6	28	0	39
Growth (%)	1.1	4.0	4.9	-0.2	3.0

China and centrally-planned Asia (CPA)

	LDV	Air	Truck	Rail*	Total
1995	14	7	51	36	108
2020	73	41	115	48	277
Change	60	34	64	12	169
Growth (%)	7.0	7.2	3.3	1.1	3.8

Latin America (LAM)

	LDV	Air	Truck	Rail*	Total
1995	62	9	86	7	164
2020	147	28	124	8	307
Change	85	19	38	1	143
Growth (%)	3.5	4.6	1.5	0.5	2.6

North America (NAM)

	LDV	Air	Truck	Rail*	Total
1995	464	54	138	45	701
2020	512	105	203	46	866
Change	48	50	66	1	165
Growth (%)	0.4	2.6	1.6	0.1	0.8

Former Soviet Union (FSU)

	LDV	Air	Truck	Rail*	Total
1995	30	8	33	6	77
2020	48	27	24	2	101
Change	18	9	-9	-4	24
Growth (%)	1.9	5.0	-1.3	-4.2	1.1

Middle East and North Africa (MEA)

	LDV	Air	Truck	Rail*	Total
1995	8	5	55	1	69
2020	22	13	73	1	109
Change	13	8	19	0	40
Growth (%)	3.8	3.6	1.2	0.0	1.8

South Asia (SAS)

	LDV	Air	Truck	Rail*	Total
1995	9	3	48	3	63
2020	58	8	96	3	166
Change	49	6	48	0	103
Growth (%)	7.8	4.5	2.8	-0.2	3.9

Other Pacific Asia (PAS)

	LDV	Air	Truck	Rail*	Total
1995	27	11	40	5	83
2020	96	31	105	4236	
Change	69	20	65	-1153	
Growth (%)	5.2	4.3	3.9	-0.9	4.3

* Including domestic waterborne
LDV = Light Duty Vehicles

Source: World Energy Council, 2000

some 61 million barrels daily in 2020.

All of these projections are based on current trends and a "business as usual" scenario. Factors that influence the growth of energy use for road transportation include the number of motor vehicles and the average use of fuel per vehicle, and the most important factor in the future size of the world's vehicle fleet is the extent to which developing Asia and Central and South America undergo rapid motorization as projected. These two regions account for over half of the estimated increase in the world vehicle total. Annual fuel use per vehicle is consistently higher in developing regions than in the industrialized countries, while vehicle energy intensity has declined in developing nations as economic development has progressed.

In many industrialized countries, traffic congestion and vehicle ownership saturation may finally limit expansion of transportation sector energy demand. Car ownership in the US and Canada is the highest in the world, and in these countries it is expected to reach saturation by 2020.[8]

Air emissions are the source of the most serious environmental impacts of road transport. Vehicle emissions commonly include carbon dioxide (CO_2), a major greenhouse gas; carbon monoxide (CO), which is toxic to humans; nitrogen oxides (NO_x), ozone precursors that harm human health; sulphur oxides (SO_x), which contribute to acid rain; and particulate matter (PM), a major cause of respiratory disease and premature death.[9] Countries that have not yet banned the use of leaded fuel also have high levels of airborne lead and of blood lead concentrations in their populations. Lead is a major health hazard and vehicle emissions are the most important source of lead exposure in many countries (see box on page 7).

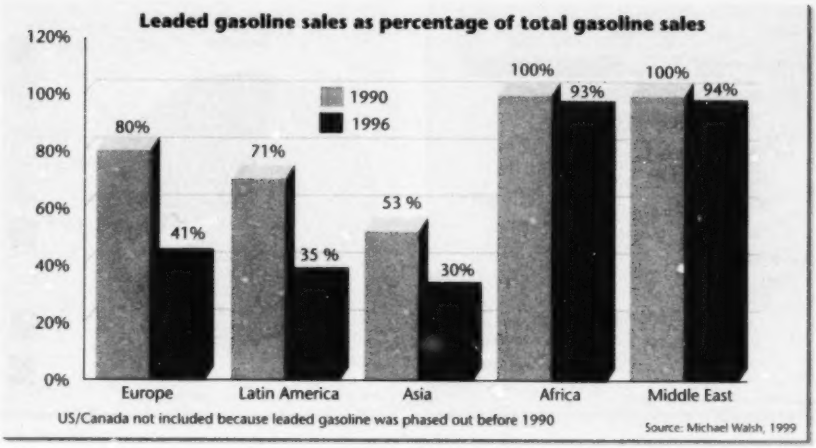
Air pollution impacts occur at three levels: urban, regional, and global. Urban impacts include the health effects of CO, lead, PM, and NO_x exposure, as well as damage to buildings and plants. Regional impacts include formation of ozone, photochemical smog and acid rain. And vehicle emissions of CO_2 are a major factor in global warming. **Table 5** shows transportation related carbon emissions for road transport as well as for the other transport modes discussed below.

The United States contributes a hugely disproportionate share, relative to its population, of global greenhouse gases and motor vehicle emissions. CO_2 makes up 85% of US greenhouse gas emissions. While the US has only 4% of the world's population, it produces over 23% of global CO_2 emissions from fossil fuel. American per capita emissions of CO_2 are about 50% higher than the average for other OECD (Organisation for Economic Co-operation and Development) countries. Transport, including motor vehicle travel, production of fuels, vehicle manufacturing, and construction of transportation facilities, accounts for some 31% of CO_2 emissions in the US – or about 5% of worldwide CO_2 emissions. No other category of energy use in North America or elsewhere accounts for a significantly larger portion of global CO_2 emissions.[10] **Figure 4** shows the projected rise in US motor vehicle travel, fuel consumption and CO_2 emissions over the next 40 years, using a

Leaded gasoline

Leaded gasoline is a major source of airborne lead emissions in many countries, especially in urban areas. Even very low lead exposure has serious effects on human health, causing damage to the nervous system, the kidneys, circulatory and reproductive systems, and other organs. Children are especially sensitive to lead exposure, which can cause irreversible brain damage, lower IQ, and developmental disorders. The use of leaded gasoline, in combination with increased urbanization and rapid growth in vehicle use, have led to high airborne lead levels, posing a major public health problem, particularly in developing-country cities.

Lead was originally added to gasoline as a low-cost way to increase its octane rating. Beginning in the 1970s, however, there were increasing public calls for reducing emissions of lead and other pollutants. Governments in many industrialized countries began to set more stringent emission standards, and to phase out leaded gasoline (see figure). Manufacturers in turn developed vehicles that didn't need lead as an engine lubricant and that were equipped with catalytic converters – to which leaded gasoline is detrimental. Almost all vehicles produced today are equipped for unleaded fuel only. However, millions of older vehicles that were designed to run on leaded fuel remain in use around the world.



It is a common misconception that only vehicles with catalytic converters can use unleaded gasoline. While such vehicles *must* use unleaded gasoline, any vehicle *can* use it, although some changes in fuel formulation may be required. A number of technical means are available to allow older vehicles to use reduced-lead or unleaded fuels. These measures are not difficult to implement, but they do entail some costs. However, the World Bank estimates that countries can save five to ten times the amount spent on converting to unleaded gasoline in health and economic savings. A number of middle- and low-income countries, including Brazil, Colombia, the Slovak Republic and Thailand, have already eliminated leaded gasoline, and Bangladesh and El Salvador, for example, achieved phase-out in only one year. Meanwhile, leaded gasoline is still common in some high-income countries.

Sources: World Bank; Michael Walsh. For more information, see: Phasing lead out of gasoline: an examination of policy approaches in different countries, UNEP, 1999.

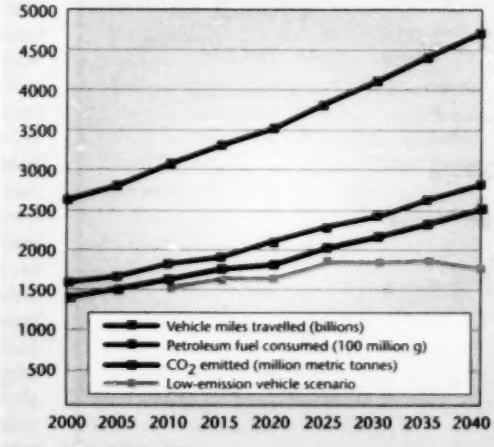
baseline scenario calculated according to current trends. It also shows the effect of greater use of low-emission vehicles or increased fuel economy on CO_2 emissions. In both cases, CO_2 emissions will be greater than those allowed under the Kyoto Protocol. Clearly these measures in themselves will not allow the US to meet the Protocol's requirements.

Urban motor vehicle ownership and use are growing faster than urban populations, with ownership rates of 15-20% each year in some developing countries. Growing road congestion in cities exacerbates the air pollution that threatens the health of urban residents (see *Industry and Environment*, Vol. 23, No. 1-2)[11] and is economically costly. The impacts of urban traffic congestion are most severe in developing country megacities, where not only intensity of road use but also the mix of vehicle types leads to almost continuous urban traffic jams (**Figure 5**).

A country need not have a high ratio of vehicles to road-kilometres, however, to suffer from serious urban congestion, as demonstrated in Canada and the US. Some countries have begun to adopt road pricing schemes to shift the cost burden to road users and discourage non-essential trips at peak times. Congestion also increases the number of accidents. The World Bank reports that about 500,000 persons die in road accidents each year in the developing countries studied. About 70% of these fatalities are pedestrians.

The transport infrastructure of roads, railway track, pipelines and other facilities can have ecological effects across broad areas, for example by altering flow of water within a regional watershed or impeding the movement of species through their natural ranges. These effects, as well as those of vehicle emissions, may be causing gradual changes in biological diversity and in ecosystems locally and regionally.[12]

Figure 4
Baseline scenario trends in US motor vehicle travel, petroleum use, and CO_2 emissions, 2000 to 2040



Rail

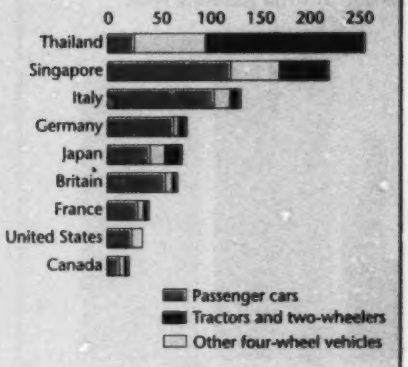
Rail transport is especially important for freight, but it also carries a high proportion of passenger traffic in some countries, notably in Europe and East Asia (**Figure 6**). Trends in passenger and freight rail use in some representative countries are shown in **Figure 7**. The generally flat trend lines for rail freight mean that while the total amount of freight carried by rail is holding steady, its overall share of the rapidly expanding freight transport market is declining.

Railroad engines fuelled by petroleum or coal have many of the same impacts as road vehicles, even if on a much smaller scale. While electric-powered systems have little impact on local air quality, they may contribute to major impacts at the site where power is generated from fossil fuels.

Air

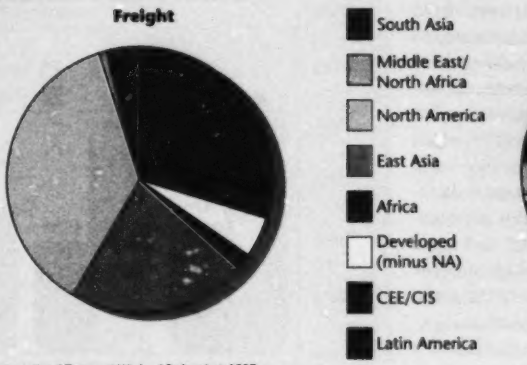
Air transport in developing countries is expected to grow almost twice as fast as in industrialized countries, as strong long-term economic growth, particularly in Asia and Central and South America, fuels an expansion in air travel. Fuel consumption for air transport is expected to account for 17% of transport energy use in 2020, up from 12% in 1996. Aviation is expected to show a faster rate of growth in fuel use energy use than any other transport mode between 1996 and 2020 on account of its slower rate of aircraft fuel efficiency

Figure 5
Vehicles per kilometre of road, 1996



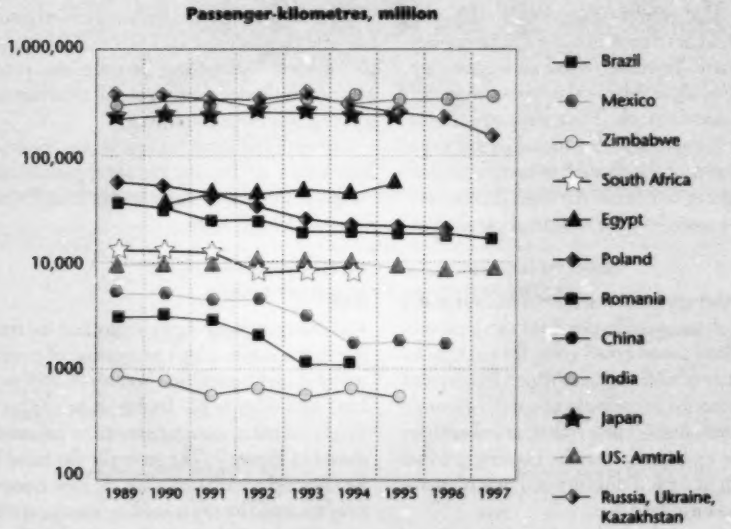
Source: International Road Federation

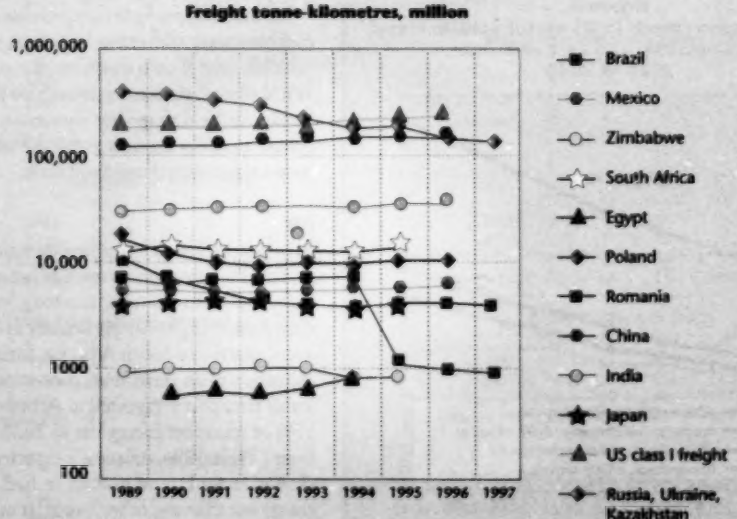
Figure 6
Rail traffic distribution



International Transport Workers' Federation, 1997

Figure 7
Rail transport trends in selected countries





Source: World Bank, 1999

improvement, as well as increasing business and vacation travel. Table 6 shows energy demand for passenger air transport in millions of tonnes of oil equivalent (Mtoe) in 1995 and projected figures for 2020.

Aircraft emit greenhouse gases including CO_2 and water vapour, as well as NO_x and SO_x compounds. At cruising altitudes they emit gases and particles directly to the upper troposphere and lower stratosphere, where they may have an impact on atmospheric composition. In 1992, aircraft were the source of about 2% of total man-made CO_2 emissions or about 13% of CO_2 emissions from all transportation sources. According to the Intergovernmental Panel on Climate Change (IPPC), air transport is responsible for about a 3.5% contribution to global warming today. This figure is forecast to rise to between 4 and 15% by 2050, despite fuel efficiency gains and other technological and operational improvements as air travel expands.[13]

Shipping

Marine transport carries a substantial portion of the world's goods, and both passengers and goods are carried by inland waterways. Reference to waterborne transport is made in some of the tables here, although that type of transport is not covered elsewhere in this issue of *Industry and Environment*. It can have significant water quality impacts in regions with heavy shipping traffic, such as the Persian Gulf and the Mediterranean.

The growth in world trade, and consequently in international shipping, has contributed to the introduction of exotic species that threaten native biodiversity in a number of regions. In North America, for example, introduction of the zebra mussel via ship ballast water in the 1980s has resulted in substantial environmental and economic damage. This small freshwater mollusc, native to Russia, has spread rapidly throughout southern Canada and the US. The zebra mussel has caused the decline of many native species and triggered large-scale changes in local food webs. It also clogs the intake structures of power plants and water treatment facilities and encrusts the bottoms of boats, adding to operational and maintenance costs.[14]

Non-motorized transport

Walking, bicycling, and use of animal carts have negligible environmental effects. They are, however, affected by the environmental impacts of motorized transport. Pedestrians and bicycles are increasingly being pushed off the road, especially in urban areas, by the growing use of cars and ever-expanding road networks. The sprawling cities of North America and Australia are notoriously unfriendly to walkers and cyclists. Even countries such as the Netherlands and China, where the bicycle has long been a major form of urban transportation, have seen a long-term decline in its transport share.

Human-powered transport needs to be included in urban mobility planning if it is to become an effective alternative to motorized transport in the developed world, and to remain so in less-developed regions, where it is often the only affordable means of transport for most people. Road safety is also a major concern in developing countries, which typically have much higher traffic death and injury rates than do industrialized countries. A high proportion of those killed or injured in developing countries are pedestrians, put in danger by inadequate or antiquated road design and high traffic density.

Towards sustainable mobility

A sustainable transportation system will require more than controlling air emissions, traffic congestion or fuel use; it must balance present and long-term needs for the environment, economic growth and equity: the "three E's" of sustainability.[15] The ultimate goal of transport is to provide access to goods, services and activities. Access is more difficult to measure than traffic (vehicle movement) or mobility (the movement of people and goods), so transport planning tends to focus on the latter. Transportation investments are often evaluated by their projected ability to reduce congestion, increase traffic speeds, or facilitate the movement of people and freight. Focusing on traffic and mobility rather than access reduces the range of possible solutions to transport problems. Telecommuting, pedestrian and cycling improvements, greater delivery service efficiency, and mixed land use are among the potential strategies to improve access without increasing traffic or mobility. Paradoxically, improvements to traffic and mobility can reduce access, as when increased vehicle traffic degrades the pedestrian environment. Automobile-oriented land use patterns can actually reduce access by dispersing activities and reducing travel choices.[16]

Because transportation is such a fundamental need, and requires such a large share of resources, transportation decisions that we make today will have long-term economic, environmental and community effects. Some of the articles in this issue focus on new or improved technologies to reduce energy consumption, air emissions, and other impacts. Others discuss transport policies, which have traditionally addressed ways to influence transport and travel patterns. Ultimately, however, sustainable mobility will depend on finding ways to decouple economic growth and transport, reducing the total demand for the latter.

Table 4
Transportation energy demand by mode (Mtoe)

	Light duty vehicles (LDV)	Air passenger	Trucking	Rail*	Maritime	Total
1995	934	151	584	120	129	1918
2020	1314	387	978	129	189	2997
Change	380	236	394	9	60	1078
Average annual rate of growth, 1995-2020 (%)						
	1.4	3.8	2.1	0.3	1.5	1.8
Modal share						
1995	49%	8%	30%	6%	7%	100%
2020	44%	13%	33%	4%	6%	100%

* Including domestic waterborne

Source: World Energy Council, 2000

Table 5
Transportation related carbon emissions (million metric tonnes of carbon)

	LDV passenger	Air passenger	Motor freight	Rail*	Maritime	Total
1995	757	121	485	99	115	1577
2020	1064	309	812	107	168	2461
Change	308	188	327	8	53	884
Growth (%)	1.4	3.8	2.1	0.3	1.5	1.8
Share of total transport carbon emissions						
1995	48.0%	7.7%	30.8%	6.3%	7.3%	100.0%
2020	43.3%	12.6%	33.0%	4.3%	6.8%	100.0%
Change	-4.7%	4.9%	2.2%	-2.0%	-0.5%	

* Category also includes domestic waterborne freight

Source: World Energy Council, 2000

Table 6
Passenger air transportation energy demand (Mtoe)

See Table 3 for regional abbreviations

	WEU	NAM	PAO	FSU	EEU*	MEA	AFR	SAS	CPA	PAS	LAM	Total
1995	37.3	54.5	13.0	7.8	na	5.3	3.4	2.8	7.3	10.9	8.9	151.1
2020	90.5	104.6	35.0	26.7	na	12.8	9.0	8.4	40.8	31.2	27.7	386.6
Change	53.2	50.1	22.0	18.8	na	7.5	5.6	5.6	33.5	20.3	18.8	235.5
Average annual growth rate, 1995-2020 (%)												
	WEU	NAM	PAO	FSU	EEU*	MEA	AFR	SAS	CPA	PAS	LAM	Total
	3.6	2.6	4.0	5.0	na	3.6	4.0	4.5	7.2	4.3	4.6	3.8

* EEU included in WEU for air transportation only

Source: World Energy Council, 2000

Notes

1. World Bank, on-line documents, 2000.
2. Ibid.
3. US Department of Energy (2000) *International Energy Outlook 2000.*
4. OECD (2000) *World Energy Outlook 2000.*
5. World Energy Council (WEC) (2000) *Energy for Tomorrow's World – Acting Now!*
6. US Department of Energy (1999) *International Energy Outlook 1999.*
7. Ibid.
8. Ibid.
9. De Souza, Roger-Mark (1999) *Household Transportation Use and Urban Air Pollution: A Comparative Analysis of Thailand, Mexico, and the United States.* Population Reference Bureau.
10. Heanue, Kevin and Susan B. Petty (1998) *Sustainable Transportation: The Road from Kyoto.* US Department of Transportation.
11. World Bank (2000) *Urban Transport Overview*, on-line document.
12. National Research Council (1997) *Toward a Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology.*
13. Intergovernmental Panel on Climate Change (IPCC) (1999) *Aviation and the Global Atmosphere.*
14. UNEP (2000) *Global Environment Outlook 2000.*
15. Heanue and Petty, op. cit.
16. Todd Litman (1999) *Issues In Sustainable Transportation.* Victoria Transport Policy Institute.

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Disruptive transportation technologies, uncompromised vehicles, and the rapid transition to hydrogen

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Summary

Vehicles some four to eight times as efficient as those of today, while equal or superior to them in all other respects, will help solve problems of air quality, oil use and obsolete industrial structure, as well as larger problems of energy (especially electricity) supply. Changes in transportation technology have the potential to become a major source of worldwide environmental and economic improvement. Revolutionary developments are already taking place in the main automaking countries. Such technological changes also present an opportunity for leapfrog development in other countries.

Résumé

Des véhicules quatre à huit fois plus efficaces que les modèles actuels, mais semblables ou supérieurs sous tous les autres rapports, pourraient aider à résoudre les problèmes de qualité de l'air, de consommation de pétrole et de structures industrielles obsolètes, ainsi que les problèmes plus généraux d'approvisionnement en énergie (en particulier en électricité). De nouvelles technologies de transport pourraient devenir une source majeure de progrès écologique et économique à l'échelle mondiale. Des innovations révolutionnaires se préparent déjà dans les principaux pays constructeurs de véhicules. Elles pourraient être aussi l'occasion, pour les autres pays, de donner un sérieux coup de pouce au développement.

Resumen

La creación de vehículos que sean de 4 a 8 veces más eficientes que los actuales, pero iguales o superiores en todo lo demás, ayudaría a solucionar los problemas de calidad del aire, uso del petróleo y vetustez de la estructura industrial, así como el más vasto asunto de la oferta de energía (en particular, la eléctrica). Los cambios tecnológicos en el transporte pueden llegar a ser una fuente relevante de mejoras económicas y ambientales en el mundo. En los países que encabezan el sector automotor, ya se aplican medidas revolucionarias. Estas ofrecen a otras naciones la posibilidad de dar grandes saltos cualitativos.

Choices made in the next five years could turn startling trends now emerging in transportation technology into global, irreversible and highly advantageous realities. With high confidence, and without compromise of quality or performance, the world could thereby:

- decouple road transport from climate and urban air quality;
- eliminate oil dependence – along with its balance of trade, economic and national security costs;
- speed a graceful transition from hydrocarbons to an economically and climatically sound hydrogen economy;
- accelerate the already rapid adoption of highly reliable and clean distributed power generation;
- reduce traffic congestion and excessive automobility, while improving affordable and equitable access;
- put early adopters firmly in the lead in building the next generation of major industries – the more profitable, benign and enjoyable successors to today's car, oil, steel, aluminium, nuclear, coal and electricity industries; and
- offer developing countries the possibility to build world-class car industries from scratch, adapted both to their own needs and to export markets.

These opportunities are summarized below, emphasizing road transport but mentioning analogous opportunities in other modes. Supporting references and details are available on request. The opinions expressed are the author's.

Advanced light vehicles

Background

Automaking – directly or indirectly accounting for as much as a seventh of GDP in the United States, and even more in some other countries – is a classic overmature industry. It sells convergent products into shrinking niches in saturated core markets at cutthroat commodity prices. Suffering from global overcapacity and consolidation, the industry yields profits that even in a good year hardly excite investors and recruits; its returns on equity rank among the lowest of any sector. It's a great industry, but a bad business.

Car-related public policy is similarly gridlocked. In the US, for example, automakers have long called for higher gasoline taxes, oil companies for stiffer efficiency standards; many environmentalists want both; most politicians want neither; and these titanic lobbies have fought each other to a draw for decades.

It's time for something completely different: a new kind of auto industry that builds on the strengths and jettisons the weaknesses of the old one, using advanced technology and entrepreneurship to bring automaking out of the Iron Age and into the Information Age. Through foresighted actions of some national and local governments, and strong initiatives by industry and NGOs, such an end-run is already well under way, chiefly in the major automaking countries. It could readily spread elsewhere.

Throughout the 1990s, governments in North America and Europe strongly reinforced private activities that changed the auto industry's perceptions of what it can, should and must do. Less than a decade ago, automakers' official view was that at most 10% fuel savings were possible without making cars unmarketable: they believed, as some economists still do, that greater efficiency must make cars undesirably small, sluggish, unsafe, and probably costly. However, uncompromised and even superior vehicles have emerged instead, and government programmes have been far outstripped by proprietary developments in the marketplace.

Over 30 firms worldwide, most of them automakers, have committed on the order of US$10 billion, doubling about every year and a half, to developing light vehicles whose light weight and low drag in moving through the air and along the road cut two- to three-fold the power needed to move them. Moreover, they use "hybrid-electric drive," turning the wheels largely or wholly with electric motors, but producing the electricity on board from fuel as needed, using small engines, fuel cells or other devices.

This combination, within a highly integrated and radically simplified design that implements functionality mainly in software ("computers with wheels" rather than "cars with chips"), is the essence of the Hypercar℠ vehicle concept developed at Rocky Mountain Institute (RMI) since

1991. In mid 1993, RMI put it largely into the public domain so that nobody can patent it. RMI's effort to maximize competition in exploiting this design's customer and manufacturing advantages has by now engaged nearly all the world's significant automakers. It is also bringing many new entrants into the market. Their transformative effect may ultimately resemble that of the aeroengine makers whose 1990s invasion of the boilermakers' turf forever changed the power plant business.

What's now possible

RMI found in 1990-91 that making the car three times lighter, using advanced polymer composites dominated by carbon fibre (aluminium is too costly and not light enough), while greatly improving aerodynamics and tyres, could open up a previously unexplored design space. Switching from internal combustion engine mechanical drive trains to hybrid-electric ones would decrease rather than increase weight, complexity and cost as smaller mechanical and electrical components, and even the elimination of many of them, created snowballing weight savings. A modern ultralight, ultra-low-drag fuel cell car with hubmotors, for example, can eliminate the engine, clutch, transmission, axles, differentials, driveshaft, U-joints, starter, alternator and more.

Since General Motors' 1991 Ultralite carbon fibre concept car (and a similar but unannounced version, built by another firm two years earlier) demonstrated the feasibility of halved mass and drag in a sporty family sedan, extensive development efforts have validated three-fold reductions in weight and drag. These in turn have permitted another breakthrough: replacing the engine and generator with the proton-exchange-membrane fuel cells about to enter the market, and feeding them what they like best – direct hydrogen, which converts fuel into motion three to four times as efficiently as a conventional car. The compressed hydrogen gas tanks are far safer than gasoline tanks, and are the strongest part of the car. Such an efficient car gets ~170 km per kg of H_2 for a large sport-utility vehicle (SUV), up to twice that for a four to five passenger family car, so hydrogen tanks adequate for a long driving range become small enough to fit conveniently into the car, rather than requiring problematic "reformers" to convert gasoline or methanol into hydrogen on board. Hydrogen infrastructure's problems have been solved, as mentioned below. With the right materials and design, superior collision safety has also been established for ultralight advanced-composite vehicles, even when they hit heavy steel ones, because the composite crush structures' five-fold greater energy absorption per kg, and the doubled efficiency of using the crush stroke, offset the ultralight vehicles' weight disadvantage.

A big American-style "suburban assault vehicle" large enough to accommodate five big adults and two m^3 of cargo, and strong enough to haul about a half-tonne up a 44% grade, can now weigh less than half as much as its conventional equivalent; be as comfortable and spacious as that heavy car, and as safe even when colliding with it head-on at about 50 km/h each; accelerate 0 to 100 km/h in about 8 seconds; provide unrivaled digital traction control; not dent, rust or fatigue; achieve a petrol equivalent of less than 2.5 L/100 km on direct hydrogen; emit only hot drinking water (it could have a coffee machine in the dashboard); be subject to none of the top 20 causes of breakdowns in today's cars; be extremely flexible, customizable and upgradeable, doing its diagnostics, tuneups and upgrades wirelessly in background; and sell for an attractive price. A family sedan could also be competitive in cost and all other attributes, but up to twice as fuel-efficient at 1-2 L/100 km.

Because its advanced-composite body could be manufactured with relatively inexpensive and ideally with soft tooling – roughly shaped by digital techniques in a few days – and no painting, such a Hypercar vehicle could also need as little as one-tenth the normal amount of capital (the main barrier to market entry), product development and tooling time (the latter is normally two years), assembly effort and space, and parts count. Early adopters therefore win. Moreover, the very low tooling and equipment cost, and the speed and agility of the product cycle, imply very low break-even volume and financial risk per model, a diverse and rapidly evolving model portfolio, and a cost-effective production scale flexible down to a microbrewery-like level.

This would permit a highly dispersed, diversified and localized auto industry with a risk/reward profile far more attractive for investors than that of today's ponderous capital- and time-intensive industry. And countries with little money but lots of brainpower could franchise or homegrow such an industry: not having an established car industry could indeed be an advantage, since the skills required are more like those of electronics, software, boatbuilding, textiles, light aerospace, and agile manufacturing. Simplified versions appropriate to countries with less technical infrastructure could also readily be adapted within the general concept.

Commercial status and prospects

An uncompromised car similar to the sport-utility vehicle has been virtually designed and built as a physical model (and is now entering detailed hardware development) by at least one group including experienced automaking organizations.[1] Such vehicles are expected to be in prototype during 2001-02 and in volume production by 2005 with a view to widespread licensing to established automakers. They could well be dominant by 2010, and the old way of designing and making cars could be fading by 2020. Some observers with excellent competitive intelligence share this view. Major automakers' aggressive pursuit of similar goals suggests that they too take it seriously, as both threat and opportunity.

Most automakers are setting less ambitious technical and market goals, but are converging with gratifying speed. At least five compact or subcompact cars in the ~3 L/100 km class are already on the market. US automakers are rolling out diverse hybrid models over the next few years. Honda will put its Insight hybrid-assisted engine driveline in all its vehicles; Toyota, its Prius engine-hybrid driveline across its full range from ultracompact cars to heavy trucks. VW, already making a 3 L/100 km city car, has announced volume production of a 2 L/100 km model during 2001-02 and a 1 L/100 km version by 2003, both made mainly of carbon fibre. BMW has said its production of a carbon-fibre high-performance car is "absolutely feasible" and may begin by 2005. Many manufacturers are nearing market introduction of composite, including advanced-composite, vehicles, some with greatly reduced drag. Engine hybrids will probably be leapfrogged by fuel cells: at least eight major automakers have announced volume production of fuel cell cars by 2004-05, several of them by 2003, and an increasing fraction now favour direct-hydrogen over on-board-reformer strategies.

So revolutionary is the accelerating pace of these developments[2] that MIT Professor Dan Roos told the Paris auto show a year ago that many of today's automakers would be out of business in a decade, put there by firms they don't now consider their competitors. He's right: the changes in platform physics, propulsion systems and design philosophies are now the greatest and fastest in a century.

Traditional automakers, however, are handicapped by serious cultural barriers in trying to change their products' materials, manufacturing methods, fuels, power plants, use of electronics and of software, design methods and business models. These barriers present competitive openings to agile and uninhibited integrators of commodity ingredients. The new competitors may be neither automakers nor from traditional automaking societies. Smart people in a warehouse in Singapore or Switzerland, Brazil or South Africa, can now threaten the world's largest industry. So can the aggressive, fast-moving "velociraptor industries" that now dominate electronic systems. They have everything it takes to make great Hypercar vehicles except experience with wheeled objects (vehicle dynamics, crashworthiness, homologation, etc.). But those car-specific skills can easily be, and are often already, outsourced to engineering service providers. If the result were badged, say, as an HP or Sun or Sony product, it might even sell better than a car with one of the traditional badges. It is sobering to recall that, in the history of technology, such game-changing "disruptive technologies" are seldom introduced by the industries that they will displace.

Accelerating the hydrogen transition

Super-efficient cars based on the design approach just described can deal profitably with not only the CO_2 emissions of road transport, but also those of the power sector, by greatly accelerating a transition to a climate-safe hydrogen economy that is profitable at each step, starting now. The strategy is described in an April 1999 National Hydrogen Association paper.[3] It rests on:

- the ability of super-efficient cars to package compressed H_2 gas tanks big enough for a long driving range, and to adopt fuel cells many years sooner because, being so light and slippery, the cars need only one-third as many kW to make them go, so they can afford three times the price per kW – a price point reached far sooner; and
- artful integration of deployment in stationary and in mobile applications, so that each reinforces the other by building production volume and cutting cost, for both fuel cells and their hydrogen appliances.

The strategy starts with fuel cells cogenerating in buildings, fuelled by on-site, miniaturized "hydrogen appliances" either reforming natural gas or electrolyzing water with off-peak electricity. Surplus hydrogen-producing capacity can also fuel cars parked nearby, so when they're parked (~96% of the time) they can sell enough electricity back to the grid at the real-time price to repay up to half the cost of owning the car. (This could displace all existing coal and nuclear plants, since a full Hypercar vehicle fleet will ultimately have ~5-10 times as much generating capacity as all utilities now own.)

As the mass-produced hydrogen appliances become cheaper, they can also go on street corners. Competition between gas and off-peak electricity to produce hydrogen, using the spare off-peak capacity of the electric and gas distribution systems that are already built and paid for, then builds enough demand to justify making bulk H_2 upstream and shipping it in converted natural gas pipeline or in new ones. Barring even better new options from renewable hydrogen research, this could be done by either of two well-established methods:

- wellhead reforming of natural gas, reinjecting the separated CO_2, and getting paid three times – for the H_2, the enhanced hydrocarbon recovery from repressurizing the reservoir, and the resequestration of the carbon – a concept that's already attracting major energy companies; or
- electrolysis with renewable electricity, whose economics will thereby improve many-fold since hydrogen competing even with US gasoline at 33¢/L, cheaper than bottled water, is equivalent to electricity selling for ~9-14¢/kWh, roughly 6-9 times the typical wholesale price of bulk electricity. Cheap hydrogen storage can also turn intermittent renewables, like wind or PVs, into valuably firm and dispatchable resources.

Even without still newer renewable hydrogen production technologies that now show much promise in the laboratory, the hydrogen economy can thus emerge from staged and modest investments, each supported by concurrent revenues. Its business case is sound, even without carbon pricing or trading. It is being rapidly adopted by large energy and car companies. Rather than relying on the price and availability of a single fuel (oil), its robust portfolio maximizes competition between natural gas and electricity feedstocks and between upstream and downstream production. Its resource base ranges from large (at least two centuries' worth of natural gas could be used in this way, profitably and without climatic harm) to inexhaustible; its climatic impact starts off small, and drops to about zero.

Parallel agendas: land-use, alternative modes, and business models

With attractive, clean, super-efficient, climate-safe vehicles, we're much less likely to run short of oil, stable climate, or breathable air. Instead, we'll run short of roads, land, and patience. Avoiding such constraints will require real competition, at honest prices, between all the ways of getting around or of not needing to. The best option is generally to be already where you want to be, so you needn't go somewhere else, which requires sensible land-use. (This means stopping the basic causes of sprawl: most countries' tendency to mandate and subsidize it. Real estate markets reveal strong demand for neotraditional layout, where nearly everyplace you want to go is within a five-minute walk.)

The second-best option is to move just the electrons and leave the heavy nuclei behind, via broadband telecommunications. The next-best option is to move the protoplasm around, but to have fair and equitable choices between all modes of physical mobility, rather than corporate socialism for private cars and free markets for everything else.

The value of making drivers pay for what they get (so they can get what they pay for) is strikingly illustrated by contrasting low-congestion Singapore with Bangkok, whose traffic congestion depresses the Thai economy by roughly one-sixth. Many important non-price policy innovations are also emerging to reinforce this result.[4] Smart highways, parking systems, and navigation/information systems – and, above all, congestion pricing of roads, bridges, tunnels, and parking – are other important parts of the puzzle. Better vehicles are important, but insufficient.

Fortunately, many major automakers are seriously examining a new business model based on providing access or mobility *services* rather than selling cars. The key is the extremely low (~4%) asset utilization of the typical private car. Car-sharing services like the German "Stattauto" exploit this through load diversity. They cut car populations by about three-fourths, and are now spreading to North America. Even better are comprehensive mobility services that combine a public transit pass with car rental/delivery and taxi backup. They let the Canton of Zürich, Switzerland, and the city of Leiden, in the Netherlands, guarantee that mobility costs will fall, but convenience will not, for anyone who drives less than 9-10,000 km a year and does not own a car.

Such a system is now going nation-wide in Switzerland (*www.mobility.ch*). While its use in most of the US would be hampered by poor mass transit, proper social costing of the externalities of driving – probably about one-third to 1 trillion dollars per year – could still justify it, especially if combined with such services as broadband Internet and video access plus a travel agency. Under a mobility- or access-based business model, a car or oil company would profit from selling *fewer* cars or litres, not more – thus aligning their interests with environmentalists'. This application of the "Solutions Economy", which is the third principle of Natural Capitalism,[5] is being taken very seriously by major automakers, some of whom see it as a key opportunity.

Other road vehicles

Hypercar-like design principles apply to vans, buses and medium lorries. Their value in heavy lorries is reduced by the dominance of tonnage rather than volume driven payloads, but remains significant. Fuel cells can also replace diesels, with no pollution and even greater efficiency. Heavy lorries would benefit greatly, too, from serious attention to aerodynamics and improved tyres. Modern informatics-based logistics could be more rapidly spread, to reduce duplicate cross-hauls and empty backhauls.

At the other extreme, light materials and hybrid drives will permit a flowering of human-electric hybrid vehicles. The third-generation electric bikes created by AeroVironment for the Oakland (California) Police Department, for example, permit even the out-of-shape to pedal up the Oakland hills, no sweat. Emerging new vehicle classes like the Swiss Twike (*www.twike.com*) or the bamboo-based CarBike (*www.carbike.de*) can combine such versatility with weather protection and, in the future, modest cost. The handicapped could benefit enormously from ultralight but very capable hybrid-electric wheelchairs, now in early development.

Rail vehicles

Rail technology strategy appears ripe for rethinking in at least two respects. First, magnetically levitated ("maglev") rail, whose vehicles float above guideways on powerful magnetic fields, looks unpromising because its extremely high capital and, often, energy cost can't address the two basic limits on rail speed – not the minimal friction of steel wheels on steel rails, but rather air resistance and right-of-way costs. Second, a new class of ultralight rail vehicle (*www.cybertran.com*) promises several-fold to many-fold lower system cost than conventional light rail, with high speed (probably up to ~240 km/h), very small footprint (~3% for the normally elevated versions), high density (two Cybertran lanes, retrofittable over most existing highway medians, can carry the traffic of four saturated highway lanes), and other advantages. It awaits a manufacturer to exploit a promising potential market.

Air traffic and cargo

Advanced engines, propellers, wings, boundary-layer control and other aerodynamic tricks, and ultralight airframes are normally said to be able to double the efficiency of modern passenger jet aircraft. However, a tripling seems likely with the latest military developments in both engines and airframes. The Lockheed Martin Skunk Works, for example, developed – but couldn't sell to the US Armed Services because it was too radical – a 95% carbon-fibre airframe for an advanced fighter plane. It was one-third lighter, yet two-thirds cheaper, than its 72% metal predecessor, because it was designed around optimal manufacturing techniques for carbon, not for metal. The most composites-intensive aircraft now in commercial service, the 777, contains only 9% composites by mass (mainly most of the tail), three times the level in the 767, but there is no good reason other than cultural conservatism why this figure shouldn't be an order of magnitude higher in civilian aircraft too.

The common view that the slightly lower airspeed of, say, ultra-high-bypass turbofan aircraft will limit their application ignores the scope for offsetting or reversing that speed loss through system improvements. Replacing central air traffic control with Global Positioning System and collision-avoidance point-to-point autonomous travel would shorten many routes and cut gate holds. Congestion-based slot fees would reduce ground and air traffic congestion. Most importantly, real competition for gates and slots would erode fortress-hub monopolies and give a fair chance to hubless airlines like most of the Southwest Airlines system in the United States.

Hubless systems offer vast potential for saving passenger time and fuel. They take you in a smaller aircraft directly to your destination, rather than in a big aircraft to a city you didn't want to go to, where you can act as "self-sorting cargo"[6] and get on another big plane bound for your actual destination. This has been sold to the traveling public as efficient and convenient. In fact, as they all experience, it takes longer and is more vulnerable to flight delays and luggage mishaps. Its sole value is to entrench hub-and-slot monopolists.

Very large fuel, pollution, and noise savings are also available from comprehensively re-engining older aircraft, especially those of the former Soviet Union and of developing countries. Zürich Airport encourages re-engining by basing its landing fees on emissions, but such fees could easily include noise as well. Obvious operational improvements could include reduced idling (some airports use towing until ready for takeoff) and using modern lightweight design and materials in on board systems, from tray-tables to entertainment systems.

It is not too early to intensify R&D on liquid H_2 and fuel cell aircraft, analogous to the existing solar-powered "eternal airplane" that can carry at most a few hundred kg indefinitely at ~18-30 km altitude, but adapted to ordinary point-to-point missions. Such aircraft could eliminate CO_2 via sustainably produced H_2. H_2O emissions would not also be eliminated, but they could be shifted from the stratosphere, where they're of greatest climatic concern, to the troposphere using the better aircraft and system designs mentioned above to operate with adequate speed at lower altitudes.

Airships now emerging from the German CargoLifter consortium and its Russian counterpart hold great promise not only for specialized heavy lifts (e.g. delivering giant turbines and alternators to remote dam sites) but also for routine containerized cargo delivery. Britain's Lucas Aerospace demonstrated long ago that small jet thrusters can permit loading dock delivery with no mooring mast, even in a gale. Desubsidization, improved intermodal coordination, and other policy and technical improvements should also yield more sensible modal splits for cargo. For many reasons, including climate, it will ultimately become desirable, even necessary, to revise the thousand or so international agreements governing aviation fuel to permit it to be taxed, removing a serious distortion that is encouraging rapid growth in air travel long after its societal marginal utility has become small if not negative.

Conclusions

Concerted attention to the opportunities described here should suffice, over several decades, to eliminate oil imports to North America, Europe, and (in concert with other kinds of energy improvements) Japan; turn the transport sector from the most recalcitrant climate-harming sector into the driver of the fastest decline in climatic risk; clean up urban air; improve the safety, affordability and convenience of access for all; enhance national security and economic stability; and transform the troubled automotive and related sectors into a durable source of competitive advantage. The basic requirements are a realignment of transport-related R&D, closer coordination between R&D and policy, greater entrepreneurship, and design integration.

These actions can make oil uncompetitive even at low prices, before it becomes unavailable even at high prices. As Don Huberts, the CEO of Shell Hydrogen, remarked in late 1999, "The Stone Age did not end because the world ran out of stones, and the Oil Age will not end because the world runs out of oil."[7] In autumn 2000, Sheikh Yamani of Saudi Arabia repeated this remark as his own. By now, the chairs of four major oil companies have said that we are entering the oil endgame and the start of the hydrogen era. Over the coming decades, oil can become – as all uranium and most coal have already become – no longer worth extracting, but good mainly for holding up the ground, because we'll have better and cheaper ways to do the same tasks. However, this cornucopia is the manual model; we must all actually go turn the crank!

Amory Lovins co-founded and co-leads Rocky Mountain Institute (www.rmi.org), an independent public charity. The applied research of its 50 staff fosters the efficient and restorative use of natural and human capital to help make the world secure, prosperous, and life-sustaining. In 1999, the commercialization of the Hypercar™ vehicle concept, which he invented in 1991, was spun off from its RMI incubator as Hypercar, Inc. (www.hypercar.com), which he chairs. "Hypercar" is a service mark of Rocky Mountain Institute.

Notes

1. J. Ball, "Dream Machine: One Quest to Build a Truly 'Clean' Car Has Gathered Steam," *Wall Street Journal*, p. 1, 9 January 2001, p. 1.
2. An open-source chronology is posted at *www.rmi.org/sitepages/pid414.asp*. This website contains more than 120 pages of introductory content about the concept, including citations to many technical papers, some of them directly downloadable without charge.
3. Lovins, A.B. and B.D. Williams, "A Strategy for the Hydrogen Transition," National Hydrogen Association, April 1999. Posted at *www.rmi.org/images/other/HC-strategyHCtrans.pdf*.
4. Many are mentioned in the latter part of Chapter 2 of the following reference.
5. Hawken, P.G., A.B. and L.H. Lovins, *Natural Capitalism: Creating the Next Industrial Revolution*. Little Brown (New York) and Earthscan (London), 1999; Bertelsmann/Riemann (Munich), 2000; Cultrix (São Paulo), 2000; Shanghai Popular Science Press, 2000; Nihon Keizai Shimbun (Tokyo), 2001; and forthcoming in Danish, Estonian, Italian, Korean, and Russian. Other translations are in negotiation. The English text may be viewed or downloaded from *www.natcap.org*, together with a *Harvard Business Review* paper summarizing the basic logic. This book for business leaders describes a way of doing business as if nature were properly valued. It turns out to be far more profitable than current practices, even today when nature is valued at zero. Natural Capitalism combines radically increased resource productivity, closed-loop and nontoxic production, a business model that rewards both these shifts, and reinvestment in natural capital.
6. This phrase and concept are due to James Womack and Daniel Jones, in *Lean Thinking*, Simon & Schuster (New York), 1997.
7. The same remark has been attributed at an earlier date to fuel cell pioneer Geoffrey Ballard. ◆

Joining forces to achieve sustainable mobility

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Summary

Using fuel cell technoogy, it will be possiole to manufacture more environmentally sound vehicles without requiring owners to sacrifice the comfort and types of equipment options they have become used to. The fuel cell vehicles being developed by DaimlerChrysler will produce very little or no air and noise pollution. The power to operate them will be generated much more efficiently than in the case of combustion engines and generators.

Résumé

Avec la technologie des piles à combustible, il devrait être possible de construire des véhicules plus respectueux de l'environnement, sans sacrifier ni le confort ni les différentes options d'équipement auxquels les automobilistes sont désormais habitués. Les véhicules à pile à combustible actuellement développés par DaimlerChrysler auront un niveau de pollution de l'air et de nuisance sonore très faible, voire nul. Leurs moteurs auront un rendement nettement supérieur aux moteurs électriques ou à combustion.

Resumen

El uso de la tecnología de la pila de combustible permitirá fabricar vehículos menos contaminantes, sin que sus dueños deban sacrificar la comodidad y el equipamiento a que están acostumbrados. Los vehículos de este tipo que desarrolla la DaimlerChrysler serán silenciosos y emitirán poco o ningún gas contaminante. La energía que emplean se produce de modo más eficiente que en los generadores y motores de combustión.

The main advantages of the fuel cell as an automotive drive system can be summed up in a few words: depending on the type of fuel used, generation of the energy needed for propulsion produces very few emissions or none at all. Moreover, this process is highly efficient. The fuel cell engine therefore satisfies demands for a substantial reduction of CO_2 emissions in the transport sector. It can do all this because it generates electrical energy directly from the controlled reaction of hydrogen with atmospheric oxygen. The by-product is chemically pure water. This type of energy conversion is far more efficient than that associated with the internal combustion engine, which creates greater waste heat that must subsequently be removed.

The fuel cell also satisfies another important requirement of future vehicular design. It reduces traffic noise. With their electric drive systems, fuel cell vehicles are extremely quiet compared to conventional vehicles with combustion drive, especially at slow speeds and when accelerating to pass; when they stop for a traffic light, fuel cell vehicles emit scarcely any noise. This characteristic makes them a genuine alternative for future use urban areas.

Many examples in recent years have shown that consumers are ultimately unwilling to pay for environmental protection by giving up convenience or accepting a higher price tag. There is hardly a customer around who would sacrifice personal comfort for the environmental soundness of a product. This is especially true in the mass-produced automobile sector, where demands for individual comfort and featured equipment share equal priority with safety and performance.

With the arrival of the fuel cell system, it is possible to produce environmentally sound vehicles with the customary quality and driving properties. Power, design and performance are perfectly complemented by the fuel cell drive's desirable and environmentally friendly attributes. Fuel cells have another important advantage: their power is generated much more efficiently than is possible using a combustion engine and generator. This advantage will become increasingly important as vehicles are equipped with more standard equipment, such as air conditioning and heating.

With the customer's needs in mind, DaimlerChrysler's short-term focus will be directed towards technical advances and reduction of fuel cell system costs.

DaimlerChrysler's mobile fuel cell

DaimlerChrysler has made significant advances in recent years, as it has striven to develop a fuel cell vehicle. As well as validating the hopes placed in fuel cell technology, these advances demonstrate the technical feasibility of the project. DaimlerChrysler is the first automaker to have advanced the hydrogen-powered fuel cell drive and its methanol-fuelled counterpart, while simultaneously demonstrating this technology's potential in passenger cars and buses. It is just five years since NECAR 1 (New Electric Car) – the world's first fuel cell vehicle – first hit the road. In the meantime, DaimlerChrysler engineers have developed solutions to all the most challenging technical problems. For example, they have:

- reduced the volume of the complete drive system by 80%;
- doubled the fuel cell drive's power while reducing its weight by half;
- modified the size of the methanol reformer, so that it can fit into a passenger car; and
- increased the operating range, so that NECAR 4 now travels five times further than the first experimental vehicle.

DaimlerChrysler is working in top gear to improve the efficiency of its fuel cell vehicles, and to continue to reduce their weight and total cost. Intensive work is also being done to ascertain which fuel is most suitable for fuel cell drives.

Given the limited nature of petroleum reserves, the importance of alternative fuels will almost certainly increase by 2020 at the latest. While worldwide demand for mobility continues to grow rapidly, fewer and fewer crude oil deposits are being discovered. The mobility of people and goods (not only one of the greatest achievements of our age, but also a key driver of the world's economy) must therefore not be allowed to depend exclusively on crude oil. This is why we need alternative fuels for the future.

To this end, "Verkehrswirtschaftliche Energiestrategie" (VES, Energy Strategy for the Transport Sector), a cooperative effort involving automobile and energy businesses, is exploring new paths in Germany. For example, in collaboration with the German government, VES tests and evaluates alternative fuels to determine their potential usefulness. The object is to focus future developments on one, or at most two, promising fuel candidates and lay the groundwork for market introduction. The results of this project are scheduled to be available early next year. They will be used by DaimlerChrysler as the basis for further activities in vehicle testing and other experimental programmes in Germany.

Comparing three alternative fuels

Fuels generated by a variety of production methods can be used to power fuel cell vehicles. In DaimlerChrysler's present view, however, hydrogen and methanol appear to hold the greatest

promise, not least because they are easy to handle from a technical point of view. They also have the lowest emissions and open the possibility of tapping renewable energy sources for mobile applications.

Hydrogen

Generating energy from hydrogen is relatively simple and highly efficient. The total efficiency of a hydrogen driven fuel cell is much greater than that of one based on gasoline or even methanol. However, the basic advantage of using hydrogen in a fuel cell is that it generates absolutely no pollutant emissions.

Hydrogen is produced mainly through the electrolysis of water, and from natural gas and by-products of the chemical industry. Electrolysis, the decomposition of water into hydrogen and oxygen through the application of electricity, is the simplest method of producing hydrogen but uses a great deal of energy. To compensate for this consumption of energy, a hydrogen-powered fuel cell vehicle must be more efficient than a vehicle with a combustion engine. NECAR 4, a hydrogen-operated fuel cell vehicle, already achieves 37% efficiency when evaluated using the "New European Driving Cycle" measurement method.

To fully harness the environmentally friendly potential of hydrogen in the long term, the electric power required for its production should come from renewable energy sources such as hydroelectricity, wind or solar power. Depending on the geographic location, thermal energy sources could also be used. The energy balance associated with all these methods, from fuel generation through its use in the vehicle, would be emission-free.

There is a problem, however: the existing infrastructure of filling stations for conventional fuels can't be used for hydrogen. In the medium term, fuel cell vehicles with on-board hydrogen storage are only suitable for fleets and motor pools that operate in a geographically limited area and can return to centrally located hydrogen filling stations. An alternative approach – use of liquid hydrogen – is now being tested in a robotic filling station at the Munich airport. Although liquid hydrogen increases the vehicle's operating range, additional energy is consumed in the liquefaction process.

In the future, all vehicles used by postal and other delivery services, taxicabs, etc. could therefore be emission-free in two important respects: they would be capable of operating without producing exhaust gases, or significant amounts of noise. The hydrogen-operated fuel cell seems to be the best of all the available options, especially for markets where legislation will require zero-emission vehicles in the foreseeable future.

Methanol

DaimlerChrysler also uses methanol as an alternative energy source in its fuel cell vehicles. Our engineers have developed a process by which hydrogen can be generated directly from methanol on board the vehicle, with the aid of a reformer. Coming up with a reforming unit suitable for everyday use meant first overcoming several difficult development hurdles. However, these hurldles had already been cleared by the time the NECAR 3 experimental vehicle hit the road. The reformer can now handle the dynamic demands associated with a vehicle in motion. For example, although cruising at a speed of 20 miles per hour requires only a small amount of hydrogen, fuel demand increases immediately when the speed increases.

The use of liquid hydrogen has a positive effect on a fuel cell vehicle's range. In the medium term, fuel cell vehicles with onboard hydrogen will be suitable for fleet and car pool use as they can return to central hydrogen filling stations. At present, such vehicles are seen as the best options for markets where legislation will require zero-emission vehicles in the foreseeable future.

One of the main advantages of the methanol reforming method is its suitability for individual mobility. Since methanol is liquid at room temperature, it could be pumped at any common filling station, along with conventional fuels such as gasoline and diesel. Thus, the introduction of methanol as a fuel would require only minor changes to equipment at filling stations.

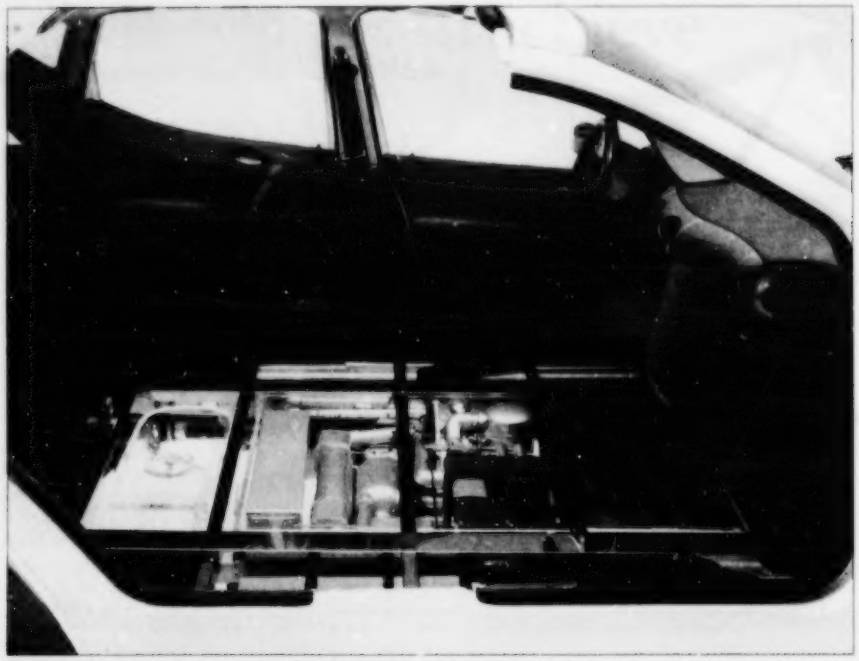
Methanol is the most suitable substance for storing hydrogen in liquid form, and therefore for operating efficient low-emission fuel cell vehicles. Unlike the use of onboard hydrogen, energy generation in a methanol-driven vehicle is not entirely emission-free. However, no nitrogen oxides (NO_x), sulphur oxides (SO_x) or soot particles are produced. Carbon dioxide (CO_2) emissions are substantially lower than in the case of internal combustion engines. A fuel cell operating on methanol emits up to 30% less CO_2 (tank to wheel) than a combustion engine operating on gasoline or diesel fuel.

Most of the methanol currently produced by the industry (about 70%) comes from natural gas. Unlike gasoline, this fuel has the advantage of not being dependent on petroleum. Natural gas continues to be available in large quantities and at many different locations. A large amount is even burned off as useless waste product during oil drilling operations. Converting natural gas into readily transportable liquid methanol would not only harness a new source of power, but also present new business opportunities for energy companies. What's more, use of methanol as a fuel would reduce dependence on politically unstable regions. Worldwide methanol production capacity for methanol exceeds 34 million tonnes annually. This capacity is currently underutilized. Even using only existing plants, it would be possible to produce the fuel required to operate between 3 and 5 million fuel cell cars.

The methanol-operated fuel cell resembles its hydrogen cousin in an important respect: the energy consumed in producing the methanol can be offset by the vehicle's high efficiency. This is now 24%, according to the New European Driving Cycle measurement method, but is expected to reach a value of up to 38% by 2010. In terms of the processes used to produce methanol industrially, there is still considerable room for improvement. In DaimlerChrysler's view, another key advantage favouring methanol use is the possibility of producing the fuel from renewable energy sources such as biomass, wood residue or garbage residues in the medium and long term. Using such sources to produce methanol would result in a neutral energy balance. This is because the CO_2 liberated in operating the vehicle would have been absorbed previously by the plants as they grew.

Gaoline

Using a completely different approach, dbb Fuel Cell Engines GmbH, a DaimlerChrysler subsidiary, is collaborating with Shell to explore gasoline (petrol) use for the fuel cell drive. Initial results will be available by the end of this year. A gasoline-operated fuel cell system has two main advantages: following minor changes, we would be able to continue using the existing infrastructure, and modifications to vehicle gas tanks would be unnecessary. However, compared with methanol, gasoline – with its high process temperatures – reduces the efficiency of the fuel cell in the vehicle. It also generates higher emissions during the reforming process. Whereas reforming a methanol-water mixture occurs at temperatures



Within the last five years, DaimlerChrysler engineers have solved the most important technical problems, reducing the fuel cell system's volume, size and weight so that it can be installed in a passenger car.

as low as 540°F (around 280°C), reforming gasoline requires a process temperature of about 1500-1800°F (800-1000°C).

Moreover, commonly used types of gasoline are not suitable for the fuel cell drive. A special type of pure gasoline (naphtha), which may only contain a specific segment of the range of hydrocarbons used in current fuels, is required. In addition, this naphtha fuel must be completely desulphurized. Naphtha does have one important advantage: its preparation requires less energy than that of hydrogen or methanol. As a result, it can actually exhibit higher efficiency in relation to the overall process.

When directly comparing different fuels, it is important to consider all the significant factors if environmental and marketing aspects are to be balanced. While hydrogen clearly earns the highest marks with respect to emission values and the reforming process, its weakness is distribution. Even if everyone agreed that hydrogen was the best alternative from a technical perspective, its use would require longer-term planning than is feasible in view of the current environmental and resource situation. As far as the gasoline fuel cell is concerned, no particular changes would have to be made to the sales network. The problem is that the technology for the mobile application is not yet available.

Without meaning to prejudge the issue (a final decision will require intensive discussions among energy suppliers, the auto industry and governments), we consider methanol the best available candidate for the average consumer. In all relevant aspects, values for the methanol-operated fuel cell lie between the extremes of those for hydrogen and gasoline. In addition, the technical feasibility of reforming has been convincingly demonstrated. Considering its availability, ease of handling and emission properties, methanol could represent the best way forward in our quest to achieve market penetration for the mobile fuel cell. What is more, methanol will be recognized as a long-term resource when prospects open up for use of the direct methanol fuel cell, which DaimlerChrysler is currently researching.

Clearly the fuel cell will not help Germany reach its short-term target of achieving roughly a 25% reduction in CO_2 emissions compared with1990 levels by the year 2005. However, this is not a valid argument against fuel cell technology. To meet such short-term climatic objectives, DaimlerChrysler is continually working on improving the internal combustion engine, a core area of expertise at the company. But as a mobile source of propulsion, the fuel cell is the alternative that can, in the long term, serve as a possible replacement for the conventional combustion engine and advance us far beyond existing environmental requirements.

The fuel cell as an environmental and economic resource

Mobility is a key factor in safeguarding the future of our economies. It therefore makes sense to ask whether we should be relying on a monocultural fuel system over the long term. With our hydrogen and methanol activities, we are creating alternatives while at the same time paving the way for integration of renewable energy into the fuel infrastructure. The diversification of available fuels should be viewed as an opportunity to open up new fields of business, characterized by a more secure future than can be expected from crude oil.

Now is the time to vigorously investigate which fuel will ultimately be used in the mass market. This is important, as these findings will certainly affect the design of future drive systems. To help resolve the fuel issue, DaimlerChrysler is initiating fleet trials with fuel cell vehicles in every key market. And it is doing so in collaboration with energy companies and governments. The trials are designed not only to generate acceptance among potential customers, but also to gather experience with mobile fuel cells and identify the fuel that best suits a given market. The collaborations involve:

- *California Fuel Cell Partnership:* As a result of a DaimlerChrysler initiative, fuel companies, automakers and public institutions are joining together in this unique public-private partnership to test fuel cell vehicles under realistic, everyday driving conditions. The collaboration also plans to promote the supply infrastructure required for large-scale introduction of fuel cell vehicles.
- *Icelandic Hydrogen and Fuel Cell Company Ltd.:* This joint venture, which includes DaimlerChrysler, Norsk Hydro (an Icelandic consortium) and Royal Dutch/Shell, is testing diverse applications of hydrogen or hydrogen carriers in combination with fuel cells. The company is also investigating which approach is better suited to the industrial production of hydrogen: electrolysis of water by water-powered current, or conversion of natural gas.
- *Activities in Japan:* In October 1999, DaimlerChrysler Japan Holding, Ltd. and Nippon Mitsubishi Oil Co., Japan's largest energy supplier, agreed to promote fuel cell vehicles in Japan jointly and to clarify infrastructure issues. Both companies are currently working on a project plan, which includes the number of test vehicles and a timetable for the programme.
- *An ethanol study in Brazil:* Ethanol is widely used in Brazil as an alternative fuel. An initial study will investigate ethanol use for the fuel cell.

Such joint activities must be substantially intensified and expanded if infrastructure issues are to be further pursued, and the fuel issue resolved, in a manner responsive to market needs. We are certain that such projects will demonstrate the positive characteristics and potential of fuel cell technology, and convince both oil companies and governments to invest in a fuel supply infrastructure for fuel cell vehicles. Automakers, for their part, have already clearly demonstrated their belief that the fuel cell should be taken seriously as an alternative drive system. For quite some time now, their technical achievements and financial commitment have been sending out a clear signal.

The important thing now is to remove all political obstacles standing in the way of the mobile fuel cell as it approaches large-scale production. Regardless of whether we're talking about North America, Japan or Europe, the development of fuel cell technology will open up new fields of business, but also require new training and production methods. To succeed in the face of strong international competition, we must begin the transformation process as early as possible.

The fuel cell is a test case for the much-touted commitment of both governments and industry to entrepreneurial risk-taking and innovation.

Fuel cell technology

A fuel cell works by combining hydrogen and oxygen in a reaction controlled by a membrane. This reaction produces electricity, heat and water vapour. If the hydrogen comes from a renewable fuel or process such as biofuel, or electrolysis via solar-generated electricity, the fuel cell can be a core element in a renewable energy system. In many ways, this type of system is the ultimate power source. The "exhaust" from a fuel cell, which combines hydrogen and oxygen to produce electricity and heat, is simply water vapour. Use the reaction in reverse-use electricity from a renewable resource to split water into hydrogen and oxygen – and a complete, cyclic and virtually non-polluting process can create electricity and heat.

Today there are five basic technologies under development for both stationary and mobile applications. For the automobile, the Proton Exchange Membrane (PEM) fuel cell is the current front-runner. Developed in the 1950s, PEM technology comes in various forms depending on choice of fuel. All of them use a platinum catalyst, embedded in a membrane that acts as a solid electrolyte. Unlike other fuel cell technologies, PEM cells have the advantage of operating at low temperatures (about 80°C). Using special "reforming" technology, virtually any hydrogen-rich fuel can be used in PEM cells, including methanol, propane, natural gas and gasoline. However, fuel cells with such reformers are more costly and complex than those using pure hydrogen.

About 30 companies are actively developing fuel cells, including all the major automobile manufacturers. The cost of fuel cells is on the same downward spiral as other renewable energy technologies (RETs).

This commitment represents a key factor in establishing new technologies that will help protect the environment, improve the economy and boost employment.

The competitive situation demands that we continue intensive development of the fuel cell if our company is to maintain its lead in its quest to produce high-performance, or low- or zero-emission, vehicles that are also a pleasure to drive. Over 60 companies internationally are currently working on fuel cell technology, including eight of the world's ten biggest revenue earners.

For quite some time now, work on the fuel cell has not been motivated exclusively by technological and environmental considerations, but has become a genuine competitive factor. It will determine the number of high-tech jobs available in the future, the degree of success enjoyed by economies around the world, and the face of future mobility. This is why we view the fuel cell as an economic opportunity. For the same reason, we're working hard to get oil companies and energy suppliers, automakers and governmental authorities to carry on the good work initiated in the VES and the demonstration projects. It is imperative that they continue their efforts to create the right framework for the successful market introduction of fuel cell vehicles. After completion of the fleet trials, this framework will have to include early agreement concerning the fuels we plan to use in the future. It will also require government action to help rapidly develop an appropriate infrastructure for the new technology.

DaimlerChrysler pledges its complete cooperation in order to achieve this goal. To this end, our company is entering into cooperative partnerships like those described above, bringing with it the knowledge already acquired from its efforts to date.

Ferdinand Panik is a member of the Directors' Committee of DaimlerChrysler AG, as well as Head of the Fuel Cell Project Group. ◆

Eco-efficient cars: an important contribution to sustainable mobility

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Sustainable development has become a global political theme since the publication of the Brundtland Commission's report in 1987 and the UN Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. Whereas sustainability has entered the political debate in many arenas, its definition has remained open. For the Volkswagen Group, the term "sustainable" encompasses the long-term, balanced maintenance of ecological, economic and social systems. As a political theme, sustainable development is also relevant to transport and to the mobility of people, goods and services.

The challenge of "sustainable mobility"

The Volkswagen Group is facing the challenges of "sustainable mobility" on several levels. On the conceptual level of future scenarios, it is actively involved in the Sustainable Mobility project of the World Business Council for Sustainable Development (WBCSD). This project's objective is the development of a global vision of mobility capable of providing improved long-term transportation of people, goods, services and knowledge that will satisfy the three dimensions of sustainability: the economy, ecology and society.

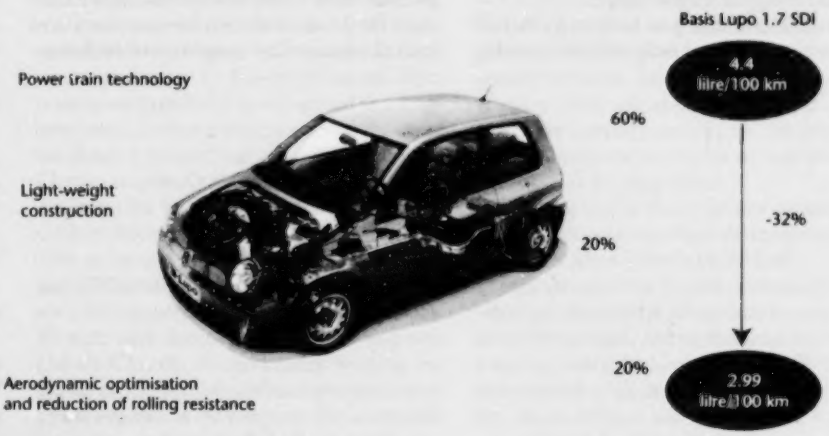
Concerning long- and medium-term activities, Volkswagen is active in research and development for new propulsion technology (e.g. the fuel cell) and modern transportation concepts. On the level of concrete product development, it is facing the challenge of sustainable development by offering ecologically efficient vehicles.

Scenarios of future market shares of different propulsion concepts show that, in the short and medium term, the classical propulsion concepts of petrol and diesel engines will continue to dominate with regard to road traffic. New propulsion concepts, such as fuel cells, will gain significance in the long term only. A study carried out by German Shell demonstrates that, up to 2020, the proportion of alternative propulsion units, including the fuel cell, will rise to a figure in the region of 7-20%.[1] A strategy for sustainable mobility must therefore take a range of timeframes into consideration. To generate impulses for future transport technology, a long-term orientation is needed. On the other hand, a sustainable mobility strategy must be founded in the present and use the potential for greater efficiency of existing technologies.

A cost-benefit analysis carried out by the German Federal Environmental Agency clearly indicates that it would be markedly less expensive to reach emission reduction targets and conserve resources in the next 10-20 years by optimizing the fuel consumption of ultra low emission vehicles (ULEVs) with combustion engines (EURO 4 standard) than would be the case using fuel cell propulsion vehicles.[2] The debate on future strategies must not be allowed to distract from contributions to sustainable mobility that could be made in the short and medium term.

Increasing global energy consumption, driven by the economic progress of developing and emergent countries, calls for immediate action capable of reducing greenhouse gases. As a member of the European Automobile Manufacturers Association (ACEA), Volkswagen has voluntarily committed itself to reducing average CO_2 emissions from new vehicles to 140 g/km by 2008. This represents a 25% reduction compared with 1995. The Volks-

Figure 1
The VW Lupo 3L TDI: measures that reduce fuel consumption



wagen Group has identified immediate measures for sustainable mobility, particularly in the following areas:

- development of innovative vehicles with highest possible efficiency, in order to implement environmental protection in series production (innovator effect); and
- integration of environmentally efficient technology in large volume series (scale effect).

The "3-litre vehicle" as an immediate contribution to environmental protection

The Volkswagen Group's market launch of the world's first series production 3-litre car, the VW Lupo 3L TDI, in the summer of 1999 was a milestone in the development of vehicles with the highest possible efficiency. Its consumption of 2.99 litres of diesel per 100 kilometres undershoots the "magic 3-litre" mark, a threshold value that has been the subject of much public debate in Germany. This consumption represents CO_2 emissions of just 81 g/km. The VW Lupo 3L TDI is also the first diesel car to comply with EURO 4 exhaust emission standards, which will not come into force until 2005. Thus it is characterized not only by its contribution to protection of the climate, but also by its reduction of exhaust gas pollution. Its low fuel consumption is the result of the development of the engine concept, combined with a wide range of innovations to reduce the unladen weight of the vehicle as well as its drag coefficient and rolling resistance (**Figure 1**).

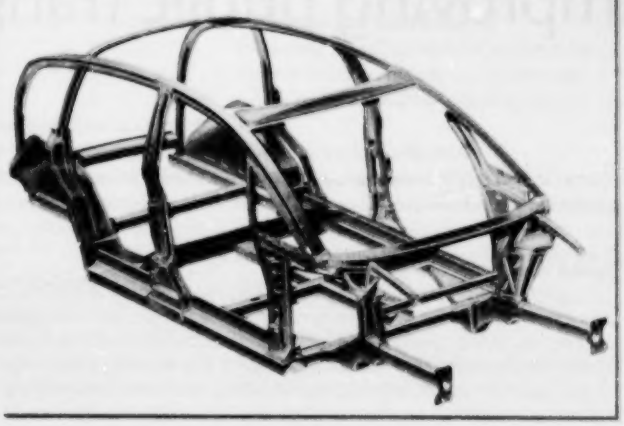
The market, press and environmental organizations have received the Volkswagen "3-litre car" favourably. Sales in Germany have exceeded Volkswagen's sales forecasts: almost every ninth Lupo sold is a 3-litre model. VCD, a German environment and transport association that annually examines the ecological characteristics of all series vehicles available on the German market, designated the VW Lupo 3L TDI best vehicle in 1999 and 2000.

The second 3-litre car in the Volkswagen Group will be the Audi A2 1.2 TDI, due to be launched at the beginning of 2001. This will be the first ever four-door compact class vehicle with fuel consumption of 2.99 litres of diesel per 100 km. It is characterised by innovative body technology and very good aerodynamics. The aluminium body with Audi Space Frame (ASF) is 43% lighter than in the case of comparable steel construction (**Figure 2**). Vehicle weight has been reduced to 825 kg. With a drag coefficient of $C_d = 0.25$, the Audi A2 1.2 TDI has the lowest air resistance recorded for a series passenger vehicle.

Reducing CO_2 emissions also has highest priority for petrol (gasoline) engines. In the autumn of 2000, the first direct injection petrol engine made by Volkswagen, the Lupo FSI, was launched on the market. It not only has low petrol consumption (a "5-litre car"), and thus CO_2 emissions of just 118 g/km, but also fulfils the most stringent exhaust emission standards. In addition to gearbox technology, this model adopts features from the 3-litre Lupo that reduce weight and aerodynamic drag.

The integration of environmentally friendly technology in the Volkswagen Group's high volume models is clearly demonstrated by the use of direct injection engine technology. In the mid 1980s, turbodiesel direct injection (TDI) technology, initially introduced for selected models only, became available throughout the Group. Dr Ferdinand Piëch, chairman of the Board of Management of the VW Group, has announced a similar strategy for integrating the new FSI (fuel stratified injection) technology.

Figure 2
ASF technology: aluminium body of the Audi A2



Without acceptance on the part of the customer, even the most environmentally friendly vehicle will be unable to contribute to environmental protection. For this reason, the market orientation of environmentally friendly vehicles is a particular challenge to the Volkswagen Group. It is no secret that society's desire for environmentally friendly cars is not automatically coupled with a readiness to pay higher prices or with public acceptance of products. Experience has shown that the public will not accept a surcharge for environmental friendliness – nor will it tolerate lower safety standards, comfort or performance. In its conception of environmentally friendly vehicles, Volkswagen has pursued the policy of "fully-fledged vehicles". The vehicles' safety, comfort and performance are of a very high standard. The marketing concept of the Volkswagen 3-litre Lupo is positively future-orientated. The car does not carry the stigma of being in any way incomplete.

Notes

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2. Kolke. R. and A. Troge (1999) Brennstoffzellen für den Straßenverkehr – eine Kosten-Nutzen-Betrachtung aus Umweltsicht. In: *Zeitschrift für die gesamte Wertschöpfungskette Automobilwirtschaft*, No. 1, pp. 68-74.

The role of information technology in improving public transport systems

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Summary
This article summarizes some improvements that could be made through applying the latest developments in information technology to the integrated management of public transport systems, including giving priority to public bus transport at intersections and increasing the quality of information provided to passengers. The number of passengers will increase as public transport conditions improve, with resulting economic and environmental benefits.

Résumé
L'article présente quelques pistes pour améliorer la gestion intégrée des réseaux de transport en commun grâce aux technologies de l'information les plus récentes, notamment en accordant la priorité aux autobus aux croisements et en donnant des informations de meilleure qualité aux usagers. Si les transports en commun s'améliorent, le nombre d'usagers augmentera, d'où certains avantages sur les plans économique et environnemental.

Resumen
Este artículo resume algunas mejoras que proporcionaría la aplicación de la tecnología informática de punta a los sistemas integrados de gestión del transporte público, inclusive la posibilidad de dar prioridad a los autobuses públicos en las intersecciones y de mejorar la información al usuario. El volumen de pasajeros aumenta según mejora este transporte, lo que produce beneficios económicos y medioambientales.

Efficient transportation systems are one of the key elements required in order to create a sound economy and a well functioning society. As cities develop economically, however, transportation systems begin to create more problems than they solve. On the passenger transport side, pressure on cities increases due to a higher percentage of private car use, as well as greater demand on the public transport network than had been foreseen. This in turn produces several types of problems:

- Congestion is an important factor with regard to the negative effects, on both citizens and the economy, of the amount of time used for transport;
- Pollution and noise are two of the negative side effects of increasing traffic; and
- Social gaps grow, as cars become status symbols and the efficiency of public transport systems decreases.

An integrated approach to these problems is important. Such an approach should include a strategy for increasing the use of public passenger transport. If made more attractive through improvements in service and quality, large numbers of people would be encouraged to continue to use (or return to using) public transport regularly. This would have a significant impact on congestion, pollution and the economy.

As a well known vehicle manufacturer, Volvo is often asked to predict how the our vehicles' technology will develop in this context. While vehicles are one important parameter, the efficiency of transportation systems is a complex issue involving many different factors. Recognition of the importance of improving not only the vehicles themselves, but also the systems in which they operate, has grown within our organization. We have developed a business unit called Volvo Mobility Systems which, for the time being, is focusing on improvement of public transport systems. One factor we believe can contribute to their efficiency is information technology. Some improvements that could be made in public transport with the help of information technology, particularly giving priority to public bus transport at intersections and disseminating better passenger information, are described below.

Priority at intersections

Buses usually experience delays and disturbances when crossing congested intersections, as they must compete with private traffic. Consequently, bus service can be slow and unreliable. When delays occur, operating speeds (dwelling time + running time/distance) fall. Disturbances at congested intersections result in poor control and coordination of bus traffic flows. Regularity and punctuality cannot be guaranteed, and a good distance between buses is almost impossible to maintain, resulting in "bunching up".

Priority can be given to buses at intersections either through traffic signals (i.e. giving special treatment to buses at signalized intersections) or through grade-separated infrastructure (i.e. tunnels or fly-overs at highly congested intersections). When such priority is given to public transport, several positive results can be observed:

Higher commercial speeds

Giving buses priority at congested intersections reduces and consolidates their run times, so that their average speed increases (i.e. dwelling times and accelerating and decelerating phases are reduced). Increasing average speed does not mean increasing vehicles' maximum speed, which could result in safety problems.

Shorter travel times

Higher commercial speeds directly increase the amount of time passengers save. Practical examples show that traffic signal priority can often provide time savings of 15-25% on a given bus route, without affecting other traffic.

Increased reliability

Fewer disturbances when crossing intersections improves the regularity of bus service. There is also an improvement in punctuality, and greater reliability of transfer connections.

Lower operational costs

Due to reduced and consolidated operation time, fewer buses are needed to provide the same level of service. As a consequence, large cost savings are possible.

Potential for increasing frequency

When operation time is reduced, bus operators can either serve routes with fewer buses and retain frequency, or serve routes with the same number of buses and increase frequency.

More attractive public transport

On-time buses, adherence to schedules, and shorter travel time can make public bus transport highly attractive. The psychological impact of giving priority to public bus transport (establishing

a local policy of "bus comes first") also enhances its public image.

Improved private traffic
Impacts on private traffic are less negative than expected. A well designed traffic signal priority system minimizes the effects on automobile travel and makes a reduction in traffic delays possible.

As priority systems are introduced, there are several other potential benefits:
- increased control and supervision of operations;
- the possibility of adding passenger information services;
- the possibility to adding operational bus management; and
- better statistics.

These benefits can be obtained through improving vehicle-to-roadside communication, vehicle-to-central-system communication, vehicle detection, and automatic vehicle localization, as well as through having efficient equipment in the vehicle.

Passenger information

In many cities it is common to find public transport systems that do not provide pertinent and convenient information to passengers. There are cases in which no information exists at all. Even if it exists, this information is often difficult to understand, outdated and/or ineffective. Passengers therefore feel lost and insecure when they use public transport.

Public transport systems can provide context-oriented passenger information either in a dynamic way (through integration of traveller information with fleet management and other operations-based systems) or in a static way (through conventional signs, route maps and timetables posted in vehicle and stations). As long as the information system helps passengers make the right travel decision, it fulfils its purpose.

Good orientation
Good, clear and simple information generally helps passengers be and feel oriented. Dynamic solutions make public transport even easier for the novice passenger, the visually and hearing impaired, and the elderly. For example, in-vehicle automatic data and voice communication helps identify bus stops when there is poor visibility or loud noise.

Time savings
Knowing where and when to go, and what bus route to take at the right time, saves passengers time. Accurate and tailored information allows them to take the shortest routes.

Smart travel decisions
A well informed travel decision not only makes the passenger's life easier, but also helps make better use of the whole public transport system.

User friendliness
Integrating dynamic and static information systems provides improved levels of customer service information to the public. It makes public bus transport more user friendly, and builds customer loyalty and confidence. Customer convenience is increased through relieving stress, uncertainty and anxiety. As many passengers whisper: "If it is late, at least I want to know how late it is so I can use my time usefully."

Integrated package
Passenger information may be offered as a part of a larger package of ITS services, such as traffic signal priority, fleet management and statistics. Such a "package" approach makes implementing passenger information systems cheaper and stronger.

Managing the public transport fleet

Currently, public transport operators are not taking maximum advantage of fully integrated advanced communications, infrastructure and equipment technologies in their bus fleets. Fleet management is therefore poor, and operational costs are higher than necessary.

Poor fleet management results in several problems:
- Resources are misused, so that costs and pollution are increased;
- By not having a management system for fleets, it is difficult to re-route or re-schedule when faced with disruption of operations. Lack of data and knowledge concerning behaviour and trends makes it difficult to plan or forecast needs and changes required for optimal operation. Not having a system that enables surveillance creates a sense of insecurity for both users and drivers; and
- Efficient fleet management can be achieved through allowing bus operators and/or local transport agencies to better manage their assets and operations. Implementing such systems would improve equipment reliability, reduce the number of delays due to equipment failure, and improve response time with regard to emergencies or other incidents. Thus it would improve customer service and reduce capital and operating costs.

Some benefits of improving fleet management are:

An integrated package
Fleet management systems may be offered as a part of a larger package of ITS services, including traffic signal priority and passenger information. Such a "package" approach makes implementing these systems both cheaper and stronger. Public transport management centres are seeking to improve their integration with subsystems, as well as with multiple operator systems and between public bus transport and other modes.

Improved management of operations and assets
There is better utilization of bus fleets, and continuous real-time monitoring of their condition (i.e. resulting in less wear and tear on vehicles). This increases efficiency and productivity and decreases costs.

Fast and reliable bus service
Such systems can streamline passenger counting, assist with flexible vehicle routing, enable timed transfer of passengers, and facilitate multiple-agency fleet management. Bus frequency and regularity can therefore be increased and travel times decreased.

Environmental soundness
Increasing the efficiency of bus operations (e.g. number of buses, routing and maintenance) will reduce pollution and fuel consumption.

Continuous data collection
Valuable information, obtained from accurate historic data, can be used in planning and forecasting use and demand. Data collection can be handled automatically through the different fleet management systems.

Increased security
Video surveillance activities deter vandalism and make passengers and drivers feel safer.

In response to the need to enhance public transport, transport authorities and bus operators are turning to advanced technologies to improve safety, efficiency and quality. Many conventional tools used in fleet management are straightforward, and are performed without using information technologies, e.g. schedule planning, staff planning, vehicle maintenance and static traffic information. However, information technology makes available a wide variety of other tools for operational use.

One integrated ITS solution is the transit vehicle tracking system, which is able to track buses against their designated route schedule. This system's core technology is Automated Vehicle Location (AVL). AVL determines where the vehicle is in relation to a map. The information can be used for a number of purposes. AVL can be integrated with systems such as:
- vehicle mechanical monitoring and maintenance;
- safety and security;
- passenger information;
- fare collection;
- automatic passenger counting; and
- traffic signal priority.

Transit vehicle tracking
This tracking system, which includes AVL and computer-aided despatching (CAD) functions, provides real-time location information for schedule adherence, dispatching and traveller information. Other ITS applications often interface, or are integrated with, this tracking system, but it focuses on providing vehicle location, schedule adherence and dispatching functions. The major components are:
- Global Positioning System (GPS) receiver;
- on-board computer (in-vehicle logic unit);
- mobile data terminal; and
- monitoring and dispatching work station and software (central hardware and software).

It is recommended that GPS technology be used for location referencing. Current radio systems can be used for communication.

Transit fixed-route software assists public transport operators in planning and operating transit fixed-route services, as well as in collecting data

for generating statistics. It performs automatic driver management assignment, vehicle monitoring and routing, and scheduling functions. Examples include run-cutting software and computer programmes that help planners develop public transport routes and schedules.

Vehicle mechanical monitoring and maintenance

A mechanical monitoring and maintenance system automatically monitors the condition of engine components, via engine sensors, and issues warnings if failures occur. This system may be linked to the transit vehicle tracking system, in order to log an incident's location and time of occurrence and transmit real-time data to the public transport management centre or depot. It can also provide vehicle diagnostics, and manages the maintenance records of transit vehicles. It may simply consist of a computer spreadsheet on which to record and monitor maintenance activity, or may be a sophisticated computerized diagnostic system.

On-board security

On-board security provides video monitoring of the bus's passenger safety environment. Video images may be recorded and later reviewed, or transmitted in real time to a central location. A silent alarm feature allows drivers to request assistance from dispatching, or directly from the authorities in an emergency. Such systems are usually linked to the vehicle tracking system.

Security of bus stops and stations

Remote real-time video monitoring and recording of the passenger safety environment at bus stops and stations allows passengers to request assistance via a two-way intercom system in case of an emergency. Monitoring is typically carried out at a central location.

The main components of such systems are closed-circuit (CCTV) cameras, video monitors, silent alarms and microphones, and a central video controller. Signs can be posted on the bus, as well as

Motorists and the environment

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This article presents a brief overview of the role motorists, the automotive sector and legislators can and should play to ensure that vehicle emissions are minimized over their life span.

We can safely assume that the vehicle population, and the urge to individual mobility, will continue to grow in the foreseeable future. Alternative fuels still do not provide an economical and acceptable alternative to today's fossil fuels. The automotive industry, manufacturers and their suppliers have made vast improvements with regard to getting vehicles to burn fuel more efficiently and in reducing their emissions. Despite the great strides made in technologies related to emissions reduction, however, we still need to address increased exhaust emissions and their environmental impact.

We must also assume that it will not be possible in the near future to establish common values for exhaust emissions on a global or other basis (reducing effective measures to national or European Union (EU) levels), or to count on individuals to be guided by their environmental consciences. Furthermore, the gap between highly developed countries and other countries with fast-growing vehicle populations concerning their exhaust emissions will continue to widen. Environmental protection costs money, and this simple fact stands in the way of harmonization.

To the author's knowledge, no manufacturer or supplier is willing or able to guarantee the emission values with which a vehicle was homologated over its entire life span. This is quite understandable, as many factors contribute to potential deterioration over the vehicle's life span, including climatic conditions, driving patterns, driver behaviour, and vehicle maintenance needs beyond the driver's control.

Some figures vividly illustrate the foregoing:

- In periodic emission testing in the United States, the overall average failure rate is 12.1%. (The average failure rate refers to failure rates vs. standards established in individual states and by the US EPA.) This breaks down into 3.3% failure on hydrocarbons (HC), 3.3% on carbon monoxide (CO) and 4.3% on nitrogen oxides (NO_x). Regarding the transient opacity test, another US EPA standard, the diesel failure rate is 11.5% at a 30% opacity cut-point.
- In Germany, 17.1% of all vehicles equipped with an electronic catalytic converter, and 18% of all diesel engine automobiles, fail periodic emission tests. Failures include visible reasons (smoke) and others involving stipulated emission values.

Such figures are astounding. To find effective remedies, all those concerned need to be part of the solution:

- legislators;
- the automotive industry, encompassing manufacturers, suppliers and the repair industry (i.e. dealers, independent workshops, quick-fit repairers, etc.);
- periodic inspection bodies; and
- motorists.

The legislative role

Environmentally relevant criteria need to integrated into driving school programmes and tests to establish conscientious driving behaviour, such as driving at revs with maximum torque, changing up early, anticipating traffic situations, avoiding unnecessary idling, and adjusting driving speeds to minimize emissions. In most countries the technical aspects of driving are kept to a minimum in driving school curricula. This is nevertheless an important area, in which legislative bodies could further the cause of the environment.

The challenge, as in most cases where changes in civic attitude are desirable, is the old principle that "no sacrifice by others can be great enough". A first step was taken in Germany, where the Road Traffic Act stipulates (with regard to driving test criteria) that "a person is fit to drive a motor vehicle if he/she has adequate knowledge of environmentally conscious and energy-saving driving techniques and is in a position to put them into practice."

In most highly developed countries, the state provides training programmes and certification for automotive mechanics and engineers. These need to be examined for their environmental content. Where necessary, adjustments should be made. This is an area in which Ministries of the Environment and of Education need to join forces. Global aid organizations with training programmes in emerging economies could also play an important part.

Countries with periodic mandated emission testing need to examine their enforcement processes. Test intervals should take into account the deterioration of emission values over a vehicle's life cycle. Frequency of testing ought to increase with the age of the vehicle, and tools such as random roadside testing, as pioneered in the European Union, or remote sensing, as pioneered in the US, need to be used. On board diagnostic systems should be evaluated for compliance and reliability over a vehicle's life span. Countries that do not have mandated emission testing should examine whether this position is acceptable today.

Another aspect to consider is the effectiveness of repairs after a vehicle fails an emission test. Uniform standards are needed to ensure uniform repair quality.

The automotive sector's role

Great technological strides have been made towards reducing emissions in new vehicles, without much regard to older vehicles or to the maintenance and repair cycles in automotive workshops with regard to exhaust emissions. Indeed, a conflict of interest is becoming evident. With the evolution of electronic components, vehicles' reliability has greatly improved and service and

at bus stops and stations, alerting riders to the fact that video surveillance activities are taking place.

Incident management system
An incident management system detects, verifies and implements incident response. For coordinated incident response and management, it allows electronic communication between public transport agencies, traffic agencies and emergency management service providers.

Public transport management centre
Bus operators may use a public transport management centre, similar to that used for trams, trains, subways and other forms of transportation, for operational control. This type of centre is often developed and supplied as a tailor-made system for each operator or group of operators. Suppliers of information technology to buses may also provide such systems. They are mainly based on state-of-the-art information technologies, software, etc. that integrate all the above technologies and more.

Conclusion

To achieve efficient implementation of a traffic information system, it is important to make the system flexible and to enable one central system to serve different purposes. At Volvo we have been developing a system that collects real time data via radio, or via road loops. Data are encoded and sent to professional users, such as traffic managers and traffic planners, and to public transport users through internet, telephone or on-site information systems. Information is provided on the current situation of the public transport system, and the future situation can predicted. A statistical data base can be created for use in traffic related planning.

If a system is built so that it can perform several functions, the efficiency of the public transport system will continuously improve and ridership will increase. This increase will benefit the economy of the public transport system, as well as attracting individual transport users and thus improving the environment and the economy in general. ◆

maintenance intervals have lengthened enormously. The profitability of automotive workshops has therefore decreased and the search for additional revenue is on, with established testing organizations being targeted and their know-how in this area being questioned. In several countries, including Austria and the Netherlands, it has already been stipulated that emission testing is to be carried out in authorized workshops.

To date, auto manufacturers have declined to establish a common interface for use of testing organizations in interrogating on board emission-sensitive systems. Authorized testing organizations' test procedures (e.g. testing at idle, testing under load, exhaust pipe testing) differ from country to country. This is unacceptable in environmental terms. Polarization in the global automotive industry should ease the problem of finding a common solution. Organizations such as ACEA (the European Auto Manufacturers Association) and FIA (the World Association of Auto Clubs) should assist in finding a solution on a mutual basis.

Since no manufacturer will guarantee a vehicle's emission values over its life span, there is still a need for supervisory testing organizations given the problems of tampering and poor maintenance of older cars. Moreover, all manufacturers have product service training programmes in-house to ensure the correct maintenance of their product range. These training programmes need to be examined for their environmental content, i.e. focus on correct functioning of exhaust emission relevant systems, which are still largely treated largely as of secondary importance.

It might be interesting to enlarge the role of warning lights, which signal malfunctioning of the catalyst or related elements. Most people tend to ignore these lights. Their vehicle continues to perform, but turns into a gross polluter. What if a warning light signalled a malfunction, and the driver therefore had a predetermined time in which to get the problem fixed before the car was disabled? Systems that can disable a stolen car are already being examined, so technically this would be quite easy to accomplish.

The role of authorized testing organizations

The principal role of testing organizations, whether state-run, private, or associations, is to test a vehicle's compliance with safety and emission standards at predetermined intervals, and to remove the vehicle from circulation, mandate repairs, or qualify it to continue circulating until the next check. Since the author, as a member of the largest US testing organization, is biased on the topic, the focus of this paragraph is on uniform standards. There are only a few organizations worldwide with such reach that, if acting in unison and with purpose, they could achieve significant results in reducing automotive exhaust emissions of older vehicles, assuming that cars up to three years old are "clean". The first of these is CITA, the world association of vehicle testing organizations, which is based in Brussels; the second is the EU's Directorate General for Transport and Energy, also located in Brussels; third would be UNEP and Working Party 29 of the UN Economic Commission for Europe.[1]

If these organizations could find ways to follow the globalization of the automotive industry, and focus on establishing uniform testing standards and procedures for emission testing, or, at a minimum, recommendations, this would represent a great step in the right direction if carried out in coordination with the main automotive manufacturers. Testing organizations also need to examine their present know-how carefully with regard to exhaust emission systems, especially the electronic elements, and ask themselves if they are adequately prepared for the future.

The motorist's role

There are six key factors involved in individual motorists' directly influencing the reduction of vehicle exhaust emissions.

- as mentioned before, *driving behaviour*. Driving within the engine's optimal torque range, anticipating traffic, avoiding unnecessary idling, and selecting the best speed in the environmental sense are some elements to consider. The correct torque range is recommended by the manufacturers and can be found in instruction manuals, where one also finds correct tyre pressures as well as recommended fuel grades and lubricants. Ignoring any of those can have a negative impact on emissions;
- *travel organization*, including route planning, avoiding unnecessary ballast on board (roof rack or weights in the boot), and avoidance of unnecessary trips;
- simple *awareness*, including watching out for excessive fuel consumption (which may have a mechanical reason), black smoke from the exhaust, or excessive noise (possibly indicating environmentally relevant vehicle malfunction);
- regular, systematic *servicing and maintenance*;
- ensuring that the vehicle is in *optimal condition* as regards engine, tyres, fuel and lubricants; and
- ensuring that the vehicle is *in compliance* and has been *emission tested* at the necessary intervals.

These are some key elements that can help reduce automotive exhaust emissions, with the focus on the individual motorist. It is not a complete survey, but represents an attempt to weigh the major elements.

Note

1. The United Nations Economic Commission for Europe (UN/ECE) Working Party on Technical Harmonization and Standardization Policies, also known as WP 29, provides a forum for debating and anticipating problems that might otherwise arise, with equal participation by all member governments concerned and by international, regional and national organizations and the private sector. It is a major concern of the Working Party to encourage the development, adoption and application of harmonized technical regulations and standards, as well as conformity assessment operations, in Member States of the UN/ECE region.

Sources for this article are the author, the German testing organization DEKRA, the US testing organization and manufacturer of emission testing equipment Environmental Systems Products (ESP), and Tom Cross, C. Eng., MIEE, ESP.

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Energy consumption during a tyre's life cycle: Michelin's commitment

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Because the car provides mobility and liberty, it is a wonderful factor in economic and social development. Today it must respond to the growing demands of the 21st century: safety and respect for the environment. Vehicle manufacturers have already integrated these expectations into their work. Tyres, as an essential part of the vehicle, must contribute to protection of the environment. In the tyre's life cycle, design, raw materials, production, use, and the end of the life cycle all have an impact on the environment. Michelin has a long-standing commitment to minimal consumption of energy, noise reduction, and assistance in the sustainable development of motor vehicles.

Tyre design and production

The simplified energy content[1] of a tyre is the total energy used in the production process, including transformation of its 200 initial and intermediary component materials. By way of example, a 195/65 R15 Energy passenger car tyre has a simplified energy content of about 9 kg.e.p.[2] This will vary as a function of different parameters: quantity and nature of the material, the tyre's architecture, production processes, and type of energy (e.g. co-generation) used. Thus a radial structure, lighter and simpler, requires 30% less energy than a cross-ply structure.

Tyre use

A moving vehicle consumes energy. The tyre is a part of this process. Road use is the most energy-consuming stage of a tyre's life cycle. Let us go back to our example. The energy necessary to produce a passenger car tyre of approximately 8 kg[1] calls for 9 kg.e.p., or 36 kg.e.p for four tyres. Over 50,000 km, a car consuming 6 l/100 km uses 3000 litres of fuel. The share of the four tyres (Green X technology) in total consumption by the vehicle amounts to 480 litres, or 360 kg.e.p Under these conditions, the tyre consumes ten times more energy than at the time of production. It is at this stage of its life cycle that the greatest effort should be made with regard to the tyre's design. It is also at this stage that the user's awareness should be heightened. Since its first automobile tyre was designed in 1895, the rolling resistance of Michelin tyres has been reduced by a factor of 3.

Noise is another phenomenon impacting on the environment. The noise emitted by a moving vehicle is partly due to the tyre's contact with the road. Studies have enabled tyre performance to be improved: on identical road surfaces, a passenger car tyre makes three times less noise today than in the 1970s, and truck tyres 2.5 times less.

End of life stage

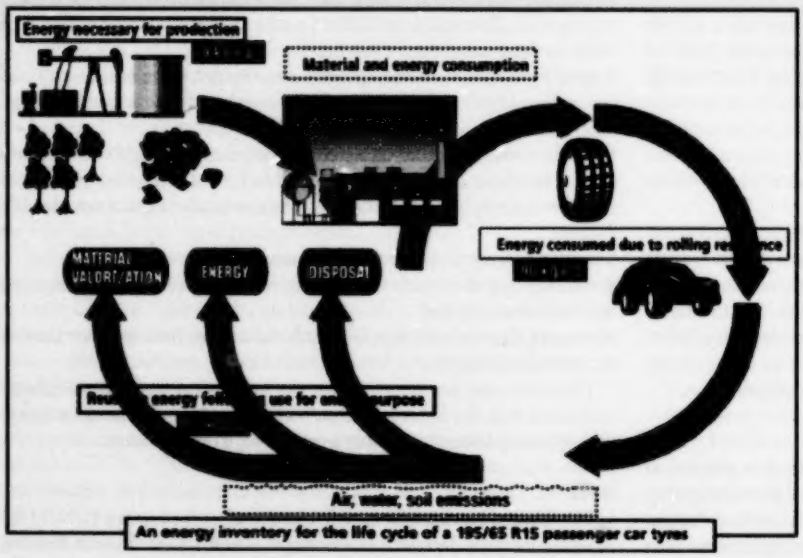
The end of a tyre's life cycle must be understood in terms of delaying as long as possible the appearance of wear, as well as increasing the value of end of life tyres through valorization.

Lengthening the tyre's life span

When a tyre becomes worn, lengthening its life span contributes to raw material and energy saving through decreasing the rate of renewal.

- Since 1946, use of the radial tyre structure has made it possible to double or even triple tyres' life span.
- The regrooving technique, used only in the case of truck tyres, consists in giving the tyre a more simplified tread pattern compared to its original pattern. The tyre's life span increases by 25% without any modification to its original performance levels.
- The retreading technique consists in replacing a worn tread with a new one. For example, with this technique the total life span of a truck tyre in the United States can be practically a million kilometres after two retreadings.

Having said this, lengthening the life span of a tyre also depends on other factors, in particular appropriate maintenance of the tyre in use.



An energy inventory for the life cycle of a 195/65 R15 passenger car tyres

Increasing tyres' value

At the end of its life cycle, the tyre can be converted back into an energy source or material. As a material it can be utilized in production of rubber products, new generation road surfaces, or even synthetic floor coverings.

As a form of energy, tyres' calorific value[3] (their sulphur content is 1%) is comparable to that of good quality coal. Different possibilities are thus explored,

Promoting vehicles that use new energy sources

Last September, along with manufacturers of vehicles and components as well as energy suppliers, Michelin organized the second **Challenge Bibendum**. This event's main purpose is to enhance the image of vehicles and manufacturers relying on new energy sources (fuel cells, electric, hybrid and solar energies, low fuel consumption engines, diester). Through a series of technical trials (noise, consumption and autonomy, driveability, acceleration, regularity), the Challenge pursued two main purposes:

- to show that these vehicles contribute reliable solutions to environmental issues (reduction of fuel consumption, pollutant emissions and noise); and
- to meet consumer demands in terms of safety, comfort and autonomy at the same time.

Measuring progress

Between 1998 and 2000, the vehicles participating in the Challenge have indeed made considerable progress:

- Fuel consumption decreased by 8% for the best petrol (gasoline)-powered vehicles participating in the Challenge and by 10% for those running on diesel. The hybrid vehicles consumed 15% less; LPG vehicles as much as 20%;
- As for vehicles with internal combustion engines, those using new energies emit ten times less noxious gases and are twice as quiet as the average vehicle in the current European fleet;
- The particle filter has proven very efficient for diesel, with CO_2 emissions decreasing sharply (less than 140 g/km);
- The progress achieved with regard to lithium batteries ensures electric vehicles a range of over 200 km and a low noise level;
- Hybrid vehicles have demonstrated their ability to reconcile autonomy, performance and low pollutant emissions in cities. In a mix use, CO_2 emissions are below 100 g/km; and
- Driving responsiveness and acceleration have improved compared with1998.

The third edition of the Challenge Bibendum in California in 2001 will allow a four-year view of the progress made by participating vehicles.

in order to recover the energy value of an end of life tyre. To return to our example, if we take as a hypothesis that the Inferior Calorific Value of a tyre is 34 MJ/kg, it is possible to recover 6.5 kg.e.p. when an 8 kg passenger car tyre is burned.

The tyre has environmental impacts at every stage of its life cycle, but the most energy-consuming phase remains that of its actual use, in which the vehicle, the tyre and the driver share responsibility.

Rolling resistance and reduction of vehicle fuel consumption

For each revolution of the wheel, under the effect of the load, the tyre is deformed. At 100 km/hour, this phenomenon takes place approximately 15 times per second. These low-frequency cyclical deformations cause the rubber to produce heat (unnecessary energy production). That is the phenomenon known as "rolling resistance".

Low rolling resistance "Green X" technology, invented by Michelin in 1992, integrates rubber mixes reinforced with silica. This innovation enables the reduction of rolling resistance, with a direct impact on vehicle fuel consumption. The tyre's performance and safety are not altered. In the example of a 195/65 R15 Energy (Green X) tyre, we have seen that the share of the four tyres in total consumption by the vehicle amounts to 480 litres. With radial carbon black based tread tyres, under the same use conditions, it would be about 600 litres. The reduction of the rolling resistance in this case is 20%. The 120 litres saved (90 kg.e.p.) can be compared with the 36 kg.e.p. needed to produce the four tyres.

Factors influencing rolling resistance

Apart from the rubber mix, other factors have an influence on the level of rolling resistance, for example road surfaces or the conditions under which vehicles are used.

According to the composition of road surfaces and their roughness, rolling resistance will be more or less noticeable. For example, let's take 100 as the level of rolling resistance on a completely smooth surface. On a medium rough surface (which is close to current road surfaces), rolling resistance is at a level of 125; it will be at 150 on a macro rough surface.

During vehicle use, drivers must pay close attention to tyre pressure and not exceed the maximum load level tyres can take. Wear level, temperature and axle alignment also directly influence the level of vehicle rolling resistance.

To better respond to the demands of the environment, the Michelin Group closely works with many car manufacturers actively participating in plans for the development of very low energy consumption vehicles.

Conclusion

Tyres play an important part in the mobility of people and goods and in transportation flexibility. The Michelin Group has taken steps to develop this primary function of the tyre, while taking into account direct and induced environmental impacts at every stage of its life cycle. This commitment reflects Michelin's unfailing will to participate in sustainable development.

Notes

1. Here the hypothesis is that a tyre's simplified energy content (cf. NF X 30-110 standard) is the total energy necessary for production of the raw material that makes up tyre composition, and that necessary for transforming these raw materials, as well as that consumed during production of the tyre. The energy content of auxiliary materials is not taken into account.
2. Hypothesis for conversion (cf. NF X 30-110 standard): 1 kg.e.p. = 11.76 kWh.
3. Inferior Calorific Value: quantity of heat emitted by unity of mass without water condensation at the time of combustion.

Sustainable distribution: opportunities to improve vehicle loading

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Summary

This article surveys opportunities to improve the utilization of road vehicles, including their potential economic and environmental benefits. Road transport's impacts on the environment can be reduced through increasing the share of freight moved in environmentally less damaging ways, increasing vehicle load factors, improving energy efficiency, and decreasing emissions per unit of energy consumed. An increase in vehicle load factors (the ratio of the weight of the goods carried to the maximum weight that could be carried) can help slow the growth of freight traffic.

Résumé

L'article passe en revue les solutions possibles pour une meilleure utilisation des véhicules automobiles, notamment sous l'angle des avantages économiques et écologiques potentiels. Pour diminuer les impacts des transports routiers sur l'environnement, on pourrait notamment augmenter la part de marchandises acheminées par des moyens de transport moins préjudiciables à l'environnement, accroître le coefficient de remplissage des véhicules, améliorer le rendement énergétique et réduire les émissions par unité d'énergie consommée. Une augmentation du coefficient de remplissage des véhicules (rapport entre le poids de marchandise transportée et le poids maximum transportable) permettrait, par exemple, de freiner la croissance du trafic de marchandises.

Resumen

Este artículo examina la posibilidad de mejorar el uso del transporte motorizado, así como su potencial de dividendos económicos y ambientales. El impacto ecológico del transporte por carretera puede reducirse, aumentado el porcentaje de carga que se desplaza por otros medios menos contaminantes, incrementando el factor de carga de los camiones, mejorando su consumo energético y reduciendo las emisiones por unidad de energía consumida. El aumento del factor de carga (la relación entre carga máxima y carga efectivamente transportada) podría ralentizar el crecimiento del transporte por carretera.

Production and distribution systems are becoming increasingly transport -intensive. In the EU, for example, the volume of freight moved, measured in tonne-km, has been growing faster than GDP and industrial output (**Figure 1**). Many transport planners and policymakers had hoped that trends in GDP and freight traffic growth, which have been closely correlated for decades, would naturally "decouple", with the latter gradually tapering. People might then enjoy the benefits of economic growth without suffering the adverse environmental effects of expanding road traffic. In practice, decoupling has occurred but in the opposite direction, exacerbating the associated environmental problems.

To limit future growth in freight tonne-km, it would be necessary to restrain or reverse the processes that have contributed to accelerating freight traffic growth (e.g. sourcing of products from further afield; subcontracting of intermediate stages in the production process to outside specialists; centralization of production, warehousing and terminal capacity). However, these processes are intrinsic to economic development and the growth of international trade. They are also likely to be relatively insensitive to increases in freight transport cost.

Prospects for suppressing growth in demand for freight transport do not look promising, particularly in the short term. It would nevertheless be possible to reduce environmental impacts by 1) increasing the share of freight moved in less environmentally damaging ways; 2) increasing vehicle load factors; 3) improving freight transport operations' energy efficiency; and 4) reducing emissions per unit of energy consumed in freight transport.

Governments in many industrialized countries have traditionally seen option 1, the "modal shift" option, as the most effective method of reducing freight transport externalities. This generally entails transferring freight from road to rail and water-borne modes, and offers the additional benefit of easing traffic congestion. The EU is promoting intermodal (or "combined") transport as the main means of achieving sustainability in the freight transport sector.

While modal shifts would usually be environmentally beneficial, their net contribution to energy and emission savings might be relatively modest. In countries where road is the dominant freight transport mode, increasing truck loading could yield greater environmental benefits. Initiatives to increase fuel efficiency in the road freight sector (e.g. though improvements in vehicle design and maintenance, fuel type and driver behaviour) have usually not considered the importance of vehicle loading.

Figure 2 compares projected reductions in CO_2 emissions in the UK from increasing truck loading by 10%; reducing empty running of road vehicles; and doubling rail freight traffic. It is arguable that road-based measures would be more achievable than doubling of rail freight traffic.

Measuring vehicle fleet utilization

Different indices can be used to measure the utilization of vehicle fleets, each giving a different impression of transport efficiency.

Tonne-kilometres per vehicle per year

The tonne-km index generally presents the trucking industry in a positive light. It is essentially a productivity indicator, measuring the average amount of work done annually by trucks. In the UK, for instance, it increased 130% between 1970 and 1996, mainly as a result of firms taking advantage of increases in maximum truck weight and running their vehicles for more hours per day. This trend impacts on the environment in several ways:

- Raising vehicle productivity reduces the real cost of transport. As transport gets cheaper, companies tend to use more of it, often internalizing transport cost savings in more centralized production and distribution systems.

Against this environmental disbenefit can be set three benefits:

- Trucks that are used more intensively wear out more quickly, shortening replacement cycles and accelerating the adoption of cleaner vehicle technology;
- An increasing proportion of deliveries are made during the evening and night, when traffic levels are low and vehicles can attain more fuel-efficient speeds. (Working at night can, of course, aggravate the problem of noise.)
- Increases in vehicle weight and size limits permit greater consolidation of loads, and hence a reduction in traffic levels. This is discussed in greater detail below.

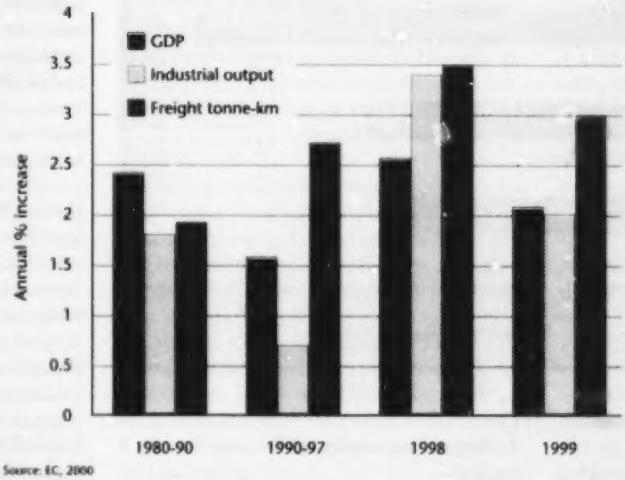
Vehicle load factors

This is generally expressed as the ratio of the actual weight of goods carried to the maximum weight

that could have been carried on a laden trip. When this ratio is plotted through time, a much less rosy picture emerges. In the UK, for example, average load factors declined from 63% in 1990 to 60% in 1999.

It is often argued that replenishing supplies on a just-in-time (JIT) basis is depressing vehicle load factors. This seems plausible, since JIT usually means delivering goods more frequently in smaller quantities. If there were a pronounced effect on the road freight system, however, one would expect to see average payload weights diminish. An analysis of official transport statistics for the UK, the Netherlands and Sweden in the period 1980-95 revealed the opposite. Average payload weight actually increased respectively by 8%, 38% and 30% (**Table 1**).

Figure 1
Relative rates of growth of GDP, industrial output and freight tonne-km in the EU



Source: EC, 2000

While JIT has unquestionably reduced average consignment weight in some sectors, this has been more than offset by consolidation of loads in others. The overall increase in average payload weight has been exceeded by the growth in vehicle carrying capacity, causing the average load factor to decline. In the absence of JIT pressures, there would probably have been a higher degree of load consolidation and possibly an increase in average load factors.

The load factor is only a partial measure of vehicle utilization. As an exclusively weight-based measure, it takes no account of the use of vehicle space or deck area, or the proportion of vehicle-kilometres run empty.

Space utilization

Many low-density products fill the available vehicle space (or "cube out") long before the maximum permitted weight is reached. In sectors characterized by low-density products, weight-based load factors tend to underestimate the true level of utilization. Where there are tight limits on a product's stacking height, loading is usually constrained much more by the available deck area than by cubic capacity. The deck area may be covered with pallets stacked to a height of 1.5 metres, leaving a metre or more of wasted space above them.

Very little research has been done on space utilization of vehicles, and few attempts have been made to collect volumetric data on road freight flows. In a study in the Netherlands and Sweden, Samuelson and Tilanus (1997) asked a panel of industry experts to estimate the average utilization of trucks, with reference *inter alia* to a series of space-related indices. This study revealed that cube utilization was typically very low, at around 28%. On average, however, just over 80% of deck area was occupied and 70% of the available pallet positions were filled. It was mainly in the vertical dimension that space was wasted, with average load heights reaching only 47% of the maximum.

In 1998, a survey of 35 fleets in the UK food sector, comprising roughly 2200 vehicles, found that on loaded trips an average 78% of the deck area and 66% of available height were utilized, corresponding to a mean cube utilization of 50% (McKinnon, 1999). A study of vehicle utilization at European level by consultants A.T. Kearney (1997) concluded that "There are 15% extra grocery trucks on European roads as a result of a failure to optimize available height." They estimated that, in addition to cutting traffic levels and emissions, more efficient use of the cubic capacity of trucks carrying grocery products could save Euro 1.8 billion.

Empty running

The most obvious form of vehicle under-utilization is empty running. Typically, around one-third of vehicle-kilometres are run empty, though this proportion varies with length of haul, type of vehicle and industrial sector. Empty running generally occurs when operators are unable to find a return load. Unlike passengers, who usually return to their starting point, most freight travels in only one direction.

In some countries, the proportion of truck-kilometres travelled empty has been declining. It fell from 33% in the UK in 1980 to 27% in 1999. This is reckoned to have saved UK industry around £1.1 billion, and to have reduced CO_2 emissions by around 1.3 million tonnes per year. An analysis of the possible reasons for this trend identified several contributory factors: longer truck journeys; an increase in the number of drops per trip; growth in the reverse flow of packaging material/handling equipment; and greater effort by shippers to obtain return loads.

It is difficult to predict how low the proportion of empty running will eventually fall. It will clearly never reach zero. A substantial proportion of "structural" empty running will remain, as a result of geographical imbalances in freight flows, vehicle incompatibility, scheduling constraints, the short length of many journeys, and risk aversion on the part of companies that are reluctant to jeopardize the reliability of outbound deliveries. But even a marginal reduction in empty running to, say, 25% would yield significant environmental benefits.

Measures to improve vehicle loading

Increased return loading

There are numerous examples of companies introducing initiatives to increase backloading in recent years. For example, Britain's largest supermarket chain, Tesco, has implemented "supplier collection" and "onward delivery" schemes. In the case of supplier collection, a returning shop delivery vehicle collects goods from a supplier's factory and carries them to the retailer's distribution centre. Onward delivery occurs when a supplier's vehicle offloads goods at the retailer's distribution centre and backloads with supplies destined for one of the retailer's shops. They are delivered on the way back to the factory, usually with minimal deviation from the direct route. Tesco has estimated that over a five-year period these schemes cut vehicle-kilometres by around 4.8 million, expenditure on fuel by £750,000 and CO_2 emissions by 23,000 tonnes (Department of the Environment, Transport and the Regions, 1998).

Advances in IT and telecommunications are

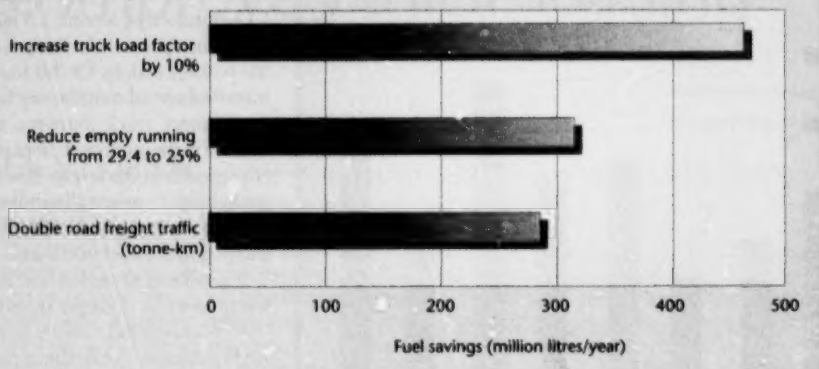
Table 1
Trends in average payload weights

	UK			Netherlands			Sweden[1]		
	Rigid	Articulated	Total	Rigid	Articulated	Total	Small	Large	Total
1980	5.3	13.9	8.5	3.5	16.0	7.4	3.3	21.0	13.7
1985	5.1	14.6	8.8	3.7	16.1	8.4	3.4	22.5	14.5
1990	4.7	14.5	8.8	4.1	16.5	9.3	3.6	24.4	15.5
1995	4.5	14.4	9.2	4.3	16.0	10.2	4.5	27.2	17.8

1. small = max. payload < 5 tonnes; large = max. payload > 5 tonnes.

Source: Netherlands Economic Institute, et al., 1998

Figure 2
Comparison of energy-saving scenarios in the UK's freight transport sector, 1995



creating major new opportunities for backloading:

• *Electronic monitoring of vehicle activity.* In-cab recording devices, supplementing conventional tachographs, provide operators with a detailed breakdown of vehicle performance and activity. This facilitates analysis of vehicle utilization across the fleet and can help identify backloading opportunities;

• *Vehicle tracking in-cab mobile data communication.* This allows vehicle schedules and routes to be replanned in real time, while the vehicle is on the road. Operators can exploit backloading and load consolidation opportunities arising at short notice. Communication with the vehicle and information on its positioning give clients greater confidence in "return load" services.

• *Development of on-line freight exchanges.* These exchanges, such as *NTE.com* in the United States and *Freight-traders.com* in Europe, enable companies to trade vehicle capacity on-line and make it easier for carriers to achieve balanced loading of vehicles in all directions.

Raising limits on vehicle carrying capacity

Very few loads simultaneously reach vehicle weight and volume limits. Most fill out the vehicle space before the weight limit is reached, or vice versa. Increasing the weight limit, or physical dimensions, of the vehicle can therefore result in greater load consolidation.

• *Maximum vehicle weight.* Within the EU, trucks engaged in cross-border transport have a weight limit of 40 tonnes. For domestic road haulage within Member States, weight limits vary from 40 to 60 tonnes. The UK government recently commissioned a detailed study of the costs and benefits of increasing maximum truck weight from 41

The new IRU Guide to Sustainable Development

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The International Road Transport Union (IRU), through its national associations in more than 60 countries, represents the entire road transport industry worldwide. It speaks for the operators of trucks, buses, coaches and taxis, from large transport fleets to driver owners. By working for the highest professional standards, the IRU aims at improving the safety record and environmental performance of road transport and ensuring the mobility of people and goods.

In 1996, in response to Agenda 21, the road transport industry, under the leadership of the IRU, the IRU Charter for Sustainable Development, a commitment by the road transport industry to drive towards sustainable development.

Implementation follows commitment

With this year's IRU *Guide to Sustainable Development*, the IRU continues its efforts to bridge from commitment to drive towards the goal of sustainable development, to factual implementation of sustainable development practices.

The IRU Guide draws on the experience accumulated by IRU Member Associations in Denmark, Germany, the Netherlands, Norway, Sweden and the UK in their national sustainable development programmes. The results of these initiatives are synthesized into six IRU modules: a practical aid for all national road transport associations and transport operators in implementing sustainable development practices. The ultimate objective of the new IRU Guide is to encourage as many road transport operators as possible to implement sustainable development practices.

Learning from the best – the six IRU modules

The IRU modules documented in the new Guide cover a wide range of activities:

Module 1: Signing the IRU Charter

The signing of the IRU Charter for Sustainable Development by individual transport operators presents the first step, and helps raise awareness and commitment among hauliers. This can go hand in hand with organizing seminars to inform transport operators about the IRU Charter and Agenda 21, or providing written information such as manuals, etc. furthering its implementation.

Module 2: Well Driven Campaign

In a Well Driven Campaign, participating operators commit themselves to improving road safety according to a certain code of good practice elaborated by the national road transport association. No third-party audit is required; participants are responsible for compliance with the campaign's code of conduct, and their success or failure is monitored by and reported to the public.

Module 3: Environmental Management System (EMS)

This module addresses the implementation and possible certification of an Environmental Management System (EMS), which is the most comprehensive and thorough way to integrate sustainable development practices into a company's every-day activities. Environmental Management Systems can use the ISO 14001 standard or one tailored for road transport, with additional criteria for transport operators but still compatible with ISO.

Module 4: Environmental Controlling

This module describes the development and application of environmental controlling tools and techniques, such as green accounting, that measure use of resources and the environmental impact of specific activities. Green accounting complements the existing financial controlling system, with which it should be integrated. Standard indicators allow benchmarking against other companies.

Module 5: Promotion of Best Industry Practices

This module covers the promotion of best industry practices, including industry awards for environmental excellence and industry reports on good practices. Through such reports, for example, road transport operators can learn from each other's efforts or about the standards set by the pioneers of the industry. Reports may be drafted in cooperation with commercial or

to 44 tonnes (for six-axle vehicles). It recognized that the resulting consolidation of loads in heavier vehicles could benefit both the economy and the environment. Environmental groups argued that this measure, by reducing the unit cost of road haulage operations, would divert freight from cleaner modes, principally rail, and would likely inflate demand for road transport. Analysis of available data indicated that, on balance, "small but significant" economic and environmental benefits would be likely to accrue from a maximum weight increase to 44 tonnes, even allowing for displacement of freight from rail to road and the generation of some additional road freight movement. Mid-range savings of around 80,000 tonnes of CO_2 and 3700 tonnes of NO_x annually could be achieved (Commission for Integrated Transport, 2000).

♦ *Vehicle size and design:* It is generally acknowledged that the average density and "stackability" of freight are declining. **Table 2** lists the major reasons for this decline, which is partly reflected in the increasing use of taller 9'6" containers in deep-sea container operations and of drawbar-trailer combinations in European road haulage. Truck dimensions are constrained by the geometry of road layouts, bridge heights and loading bays, and by the height of bridges and tunnels. Where the transport infrastructure permits an increase in vehicle height, the insertion of an extra deck could allow firms to make more effective use of vehicle space. In the UK, where most roads have five-metre height clearances, double-decking of articulated vehicles carrying low density products could cut haulage costs by around £340 million per year and CO_2 emissions by 0.5 million tonnes per year.

♦ Vehicles can also be redesigned in other ways to permit greater load consolidation. Compartmentalization of trucks has enabled grocery retailers and their contractors to combine the movement of products at different temperatures on a single journey. This form of "composite distribution" enabled the UK retailer Safeway to reduce the average number of vehicle trips required to deliver 1000 cases from five in 1985 to one in 1995.

Use more space-efficient handling systems and packaging

The efficiency with which a vehicle's cubic capacity is used partly depends on the nature of the packaging and handling equipment. Companies must reconcile the desire to maximize vehicle fill with the need to protect products from damage in transit, and to minimize handling costs. The following examples illustrate the effects handling/packaging changes can have on the transport operation:

♦ *Choice of loading method.* A large mail order company managed to improve vehicle cube utilization and cut vehicle-kilometres by 6% through loading parcels loose rather than in bags;

♦ *Nature of the handling system.* By using wooden pallets rather than roll cages, a grocery retailer can load 15-20% more cases onto a conventional trailer;

♦ *Stacking height.* One manufacturer of soaps and detergents calculated that by increasing pallet height from 1.7 to 2.1 metres, it could reduce its road freight demand by 1.6 million truck-kilometres per year. As the pallet slots in most warehouses offer only 1.7-1.8 metre clearance, however, such a change would require reconfiguration of racking systems;

♦ *Modular loads.* A French food manufacturer improved vehicle fill by 35-41% by packing orders into modules of varying heights (University of St. Gallen, 2000);

government partners. These could be helpful in encouraging widespread adoption of best industry practices identified.

Module 6: Driver Training

This module addresses the human element through the training of bus, coach and truck drivers – aimed at improving road safety, fuel efficiency and load security. The philosophy behind this module is that well trained and motivated drivers are involved in fewer accidents, use less fuel, are more reliable and customer-oriented, and know their responsibilities vis-à-vis the environment and other road users.

Benefits for the environment and transport operators

Although sustainable development has a wider meaning, the six IRU modules aim at achieving the following specific sustainable development objectives:

♦ to create awareness among transport companies of the objectives and benefits of sustainable development;
♦ to improve safety and reliability of transport;
♦ to improve resource efficiency, especially fuel consumption;
♦ to reduce emissions (primarily of CO_2, CO, HC, SO_2, NO_x and particulates); and
♦ to reduce noise, especially at company sites and in inner cities.

Measures aimed at improving safety, environmental performance and fuel efficiency can at the same time improve operators' profitability and quality of service. Lower fuel consumption means not only reduced CO_2 and other emissions, but also lower fuel costs. Improved safety means fewer accidents, more reliability and less vehicle downtime, as well as lower insurance costs. Improved waste water management can reduce a company's water bill significantly.

Compilations of practical examples, available on the IRU web site, demonstrate how effectively IRU modules and national programmes can put the environment and the transport operator's business needs in a win-win situation.

Road transport companies, which, for example, implemented IRU module 3 (Environmental Management System), reported after a successful implementation:

♦ a reduction of waste water and waste oil of between 40 and 95%;
♦ a reduction of several tens of thousands of litres of diesel fuel per year; and thus
♦ a substantial reduction of particulates and CO_2 emissions.

Incentives – the accelerator for implementation

A critical success factor for accelerating implementation will be effective incentive schemes, set up by governmental partners of the road transport industry, to further encourage use of the latest available technology and best industry practices. Transport operators who implement the IRU modules, and who make corresponding efforts and investments in new equipment and practices, should be recognized and rewarded accordingly.

These incentives could include preferential taxation for environmentally friendly vehicles and cleaner fuels, or user advantages for those operators who have implemented sustainable development practices as set out in the IRU Guide.

Outlook – what's next on the IRU agenda

The IRU will continue its engagement for achieving sustainable development. Promoting implementation of sustainable development practices and its monitoring has become a key priority for the IRU and its Member Associations.

In cooperation with its Member Associations, and national and international governmental and commercial partners, the IRU will encourage and, where necessary, coordinate implementation of further national programmes aimed at making a positive contribution to sustainable development, based on the IRU modules.

As a follow-up activity to its Guide, the IRU will elaborate a *Report on Best Industry Practices*, containing practical examples of industry forerunners worldwide, aimed at achieving sustainable development in the road transport industry. The description of these best industry practices will include quantification of the benefits for the environment achieved by each measure taken.

Web site: www.iru.org.

Table 2
Reasons for declining freight density and stackability

❶ ***Change in the nature of the products.*** Many consumer products have become lighter over time, as plastic and other synthetic materials have increasingly replaced metal, wood and leather. Miniaturization of components has also reduced the weight of many appliances. A new generation of products has emerged in sectors such as electronics, sports equipment, toys and do-it-yourself (DYI) that are intrinsically of low density.

❷ ***Increased packaging.*** The move to self-service retailing, the growth of processed foods, and more intensive use of packaging as an advertising medium have greatly increased the amount of packaging. Many of the new electrical and electronic products are also very fragile, requiring thicker layers of protective packaging. As this packaging is very light, increases in the ratio of packaging volume to product volume reduce the average density of freight consignments.

❸ ***Greater use of unitized handling equipment.*** The growth of "palletization", and increased use of roll/cage pallets, has enabled firms to improve the efficiency of handling operations at the expense of vehicle utilization. This handling equipment takes up space in the vehicle, and again reduces average weight/volume ratio for the overall payload.

❹ ***Declining "stackability".*** In some sectors, the increasing fragility of the product (and weakening of packaging material) is limiting the height to which it can be stacked. In the food and drink industry, cans have become thinner and rigid cardboard, plastic, or even wooden boxes been replaced by cardboard trays which offer little vertical support.

❺ ***Order-picking of palletized loads at an earlier stage in the supply chain.*** Traditionally, distribution of manufactured products from the factory to the customer's warehouse was supply-driven, with pallets loaded to maximum height with a single product line and standard packaging. The flow of products at the upper levels of the supply chain is now becoming demand-driven, forcing manufacturers to assemble mixed orders for individual retail and wholesale customers. Pallet loads of mixed products tend to be lower, have an irregular profile, and offer less opportunity for stacking.

❻ ***Tightening health and safety regulations.*** These regulations have restricted the height to which pallets can be stacked during loading and unloading. This, too, has the effect of reducing the amount of freight that can be carried on each square metre of vehicle deck area.

◆ *Shape and dimensions of product packaging*: By marginally redesigning its packaging, a Japanese printer manufacture saved around 60,000 vehicle-kilometres per year.

Adoption of more transport-efficient order cycles

The nature of the order filling process can have a significant impact on the efficiency of the transport operation. There are ways this process can be modified to allow firms to increase the degree of load consolidation, and hence reduce truck traffic levels. For example:

◆ *Adoption of the Nominated Day Delivery System (NDDS).* Firms operating this system achieve much higher levels of transport efficiency by encouraging customers to adhere to an ordering and delivery timetable. Customers are informed that a vehicle will visit their area on a "nominated" day, and that to receive a delivery on that day they must submit their order a certain period in advance. The advertised order lead time is thus conditional on the customer complying with the order schedule. By concentrating deliveries in particular areas on particular days, suppliers can achieve higher levels of load consolidation, drop density and vehicle utilization. Some managers reject this system on the grounds that it would weaken their company's competitive position, and probably result in sales losses in excess of the transport cost savings. The experience of many of the businesses that have applied NDDS contradicts this view.

◆ *Abandoning the monthly payment cycle.* Many companies invoice their customers at the end of each month, giving them an incentive to order at the start of the month and thereby obtain a longer period of interest-free credit. This can induce wide monthly fluctuations in freight traffic levels, making it difficult for firms to manage their vehicle capacity efficiently. By abandoning the monthly payment cycle and moving to a system of "rolling credit", which computerized financial accounting systems now facilitate, firms can increase the average level of vehicle loading and reduce traffic levels. One confectionery manufacturer has estimated that this measure could allow it to reduce truck-kilometres by 10%.

Sharing vehicle capacity

During the 1980s and 1990s, there was a sharp increase in the proportion of road haulage services provided on a dedicated basis for individual clients. Dedication of services denies carriers the opportunity to perform their traditional "groupage" role and, as a result, carries a vehicle utilization penalty. However, there is evidence that in several European countries major users of dedicated services have been granting contractors the freedom to carry other firms' traffic in their vehicles. In the UK, several company-sponsored studies of the potential benefits of shared-user services in the automotive, consumer electrical and clothing sectors (in each case replacing four or five separate dedicated services) have indicated that this can reduce truck-kilometres by around 20%.

Conclusions

For environmental reasons, it may become necessary in the longer term to restrain the underlying growth of freight movement. In the short to medium term, it should be possible to mitigate the effects of this growth by making better use of vehicle capacity. Increasing vehicle load factors effectively reduces the ratio of vehicle-kilometres to tonne-kilometres, moderating the growth of freight traffic on the ground. This article has outlined different ways of improving vehicle loading. Although many have the potential to cut vehicle-kilometres by only a small margin, collectively they could have a substantial impact on freight traffic levels, fuel consumption and related emissions.

To heighten awareness of the vehicle loading issue, traditional fuel efficiency measures should be supplemented by an analysis of energy intensity, expressed as the energy required to move specific units of freight rather than vehicles. Variations in the energy-intensity of distribution operations in the food sector suggest that disseminating current best practice could yield significant savings both in emissions and operating costs.

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Civil aviation and the environment

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Summary

The ICAO Council's Committee on Aviation Environmental Protection (CAEP) addresses the main environmental problems associated with civil aviation: aircraft noise, and emissions from aircraft engines. Reduction at source is the main focus of CAEP work on aircraft noise, but noise abatement and land-use planning also receive considerable attention. Work on emissions falls into three categories: technology and standards, operational measures, and market-based mechanisms. ICAO provides environment-related assistance to countries through technical cooperation and training programmes.

Résumé

Le Conseil de l'OACI comprend un comité pour la protection de l'environnement en aviation (CAEP) chargé d'étudier les principaux problèmes d'environnement liés à l'aviation civile : nuisances sonores et émissions des moteurs. Si le travail du CAEP est principalement centré sur la réduction du bruit à la source, l'atténuation des nuisances sonores et l'aménagement du territoire ne sont pas négligés pour autant. Quant au travail sur les émissions, il s'effectue dans trois directions : la technologie et les normes, les mesures opérationnelles et les mécanismes soumis au lois du marché. A titre d'assistance, l'OACI propose aux pays intéressés des programmes de coopération technique et de formation dans le domaine de l'environnement.

Resumen

El Comité de Protección Medioambiental en la Aviación CPMA del Consejo de la OACI se ocupa de los principales problemas ambientales que plantea la aviación civil: el ruido de los aviones y la emisión de sus motores. En cuanto al ruido, el trabajo del CPMA e orienta a la implantación de motores más silenciosos, pero también presta mucha atención a la insonorización del entorno y la planificación del territorio. Respecto a las emisiones, se trabaja en tres ámbitos: tecnología y baremos, medidas operativas y mecanismos de mercado. La OACI facilita ayuda a diversos países en temas medioambientales, mediante cooperación técnica y programas de formación.

The importance of noise and other environmental issues for the aviation industry has grown considerably since the late 1960s, when the International Civil Aviation Organization (ICAO) first became involved in environmental matters. The Organization's current environmental activities are largely undertaken through its Committee on Aviation Environmental Protection (CAEP), which is composed of experts from States, major sectors of the aviation industry, and an environmental umbrella group.

The Committee deals with the main environmental problems associated with civil aviation, namely aircraft noise and the impact of aircraft engine emissions. The guiding principles underlying its work are technical feasibility, economic reasonableness, and environmental benefit. ICAO standards and recommended practices (SARPs) relating to environmental protection are contained in Annex 16 to the *Convention on International Civil Aviation* (the Chicago Convention, 1944), while ICAO policies in this area are contained in a resolution adopted by the 32nd ICAO Assembly in autumn 1998.[1]

ICAO also assists States through its technical cooperation programme, providing the necessary expertise to help address environment-related issues affecting aviation. In addition, the ICAO Trainair programme has begun to get involved in environmental protection matters. It recently developed a course on airport noise assessment to help instruct and train personnel in this field. (The ten-year-old Trainair programme was developed by ICAO to improve the effectiveness and cost efficiency of civil aviation training in developing countries.)

Aircraft noise

There are three main themes to CAEP's work in the noise field: reduction at source, use of noise abatement operating measures, and land-use planning.

Reducing noise at source

Reducing noise at source has long been the primary focus of CAEP's work. In the 1970s, ICAO established noise certification standards in Annex 16. The initial standards for jets (aircraft designed before 1977) were included in Chapter 2 of Annex 16. Subsequently, newer aircraft were required to meet the stricter standards contained in Chapter 3 of the Annex. CAEP is now exploring the scope for a new noise standard more stringent than that contained in Chapter 3.

Almost a decade ago, an extraordinary session of the ICAO Assembly adopted a comprehensive policy on noise issues, including specific revisions regarding operating restrictions on noisier aircraft. In considering proposals by some States to restrict the operations of aeroplanes that exceed Chapter 3 noise levels, the ICAO Assembly of 1990 succeeded in developing a compromise solution. States with noise-sensitive airports could impose restrictions on operations of noisier aircraft if they so wished, but only under certain conditions. The restrictions could only be introduced gradually, and problems faced by operators from developing countries had to be taken into account. The resolution also included a provision urging States not to impose any restrictions on Chapter 3 aircraft.

The adoption of the resolution, by consensus, was the culmination of four years of analysis and development by the ICAO Secretariat, the Council and the Assembly itself. The outcome was seen as a substantial achievement, considering the wide differences around the world in environmental pressures and in air carriers' economic circumstances.

In recent years, governments have been turning their attention to the situation that will exist once operations of Chapter 2 aircraft at their airports are largely replaced by Chapter 3 aircraft. There are concerns that the rapid growth of air transport could increase noise levels once again. A consensus has yet to emerge in ICAO on how to address these concerns.

European governments have focused on preventing an increase in operations of aircraft which have been recertificated to Chapter 3 standards through re-engining or hush-kitting. While this pertains to European airports only, it could impact on carriers based elsewhere and has raised questions within ICAO about consistency with the compromise solution of 1990, as well as the possible impact on ICAO's worldwide noise standards. In April 1999, the EU Council adopted a regulation[2] on this subject which became applicable on 4 May 2000. That regulation recently became the subject of a complaint filed by the United States with ICAO, under the Chicago Convention's provisions for settling disputes (Article 84). The relevant procedures for dealing with such issues are now under way.

In June 1999, in light of these developments, the ICAO Council decided to expand CAEP's mandate in the noise field. In addition to work

already under way concerning a new noise standard more stringent than Chapter 3, CAEP is now exploring the issue of possible operating restrictions on Chapter 3 aircraft from a worldwide perspective. It has been requested to develop technical options for consideration by the Council in 2001.

CAEP will be making use of a new analytical tool, the Model for Assessing the Global Exposure to the Noise of Transport Aircraft (MAGENTA). The model will estimate the benefits of policy measures to reduce noise, in terms of changes in the number of people who would be exposed to a given level of noise. While information about the estimated benefits was sometimes available for a particular airport, until now there has been no reliable means of extrapolating this information to cover many airports. Using MAGENTA, it should be possible to estimate the benefits of different options on both a regional and worldwide basis.

Noise abatement operating measures

While CAEP's primary focus has been on reducing noise at source through certification, or through restrictions on noisier aircraft, there is some scope for alleviating the impact on neighbouring communities through noise abatement operating measures. There are several methods of achieving noise abatement. Examples include preferential runways and routes, and noise abatement procedures for take-off or for approach and landing. The appropriateness of any of these measures depends on the physical lay-out of the airport and its surroundings, but in all cases priority must be given to safety considerations.

In 1995, CAEP recommended new take-off noise abatement procedures. These have since been given a thorough review by safety experts and are expected to be considered by CAEP at its next full meeting in January 2001.

Land-use planning

Land-use planning is one effective means to ensure that activities near airports are compatible with aviation. Its main goal is to minimize the size of the population affected by aircraft noise through introducing land-use zoning. Compatible land-use planning and control is also a vital instrument for ensuring that the gains achieved by reducing the noise of the latest generation of aircraft are not offset as a result of further residential development around airports.

ICAO guidance on land-use planning is contained in the *Airport Planning Manual* (Part 2C, Land-Use and Environmental Control). A revised edition of this manual (Document 9184) is being prepared by CAEP and is expected to be published shortly. The Manual, which provides guidance on using various tools for minimizing the impact of aircraft noise in the vicinity of airports, describes the practices adopted for land-use planning and control in several States.

Aircraft engine emissions

Aircraft engines burn fuel, producing emissions. The impact of these emissions gives rise to concerns at both ground level and the global level, where the principal concern is aviation's contribution to climate change.

In the immediate vicinity of airports, concerns focus on the potential health and environmental effects of emissions such as nitrogen oxides (NO_x) and particulates. Also at ground level, but more widely spread, there are concerns that aircraft engine emissions such as NO_x may be contributing to acid rain.

In *Aviation and the Global Atmosphere*, a special report prepared by the Intergovernmental Panel on Climate Change (IPCC) at ICAO's request and published in 1999, aircraft are said to contribute about 3.5% of the total radiative forcing by all human activities, a proportion predicted to grow in the future.[3] Emissions from aircraft that affect climate change include carbon dioxide (CO_2), water vapour, NO_x, sulphur oxides (SO_x) and soot. Depletion of the ozone layer does not appear to be an issue insofar as emissions from the present subsonic fleet are concerned, but could become one if there were to be a significant fleet of supersonic aircraft.

Adoption of the Kyoto Protocol to the UN Framework Convention on Climate Change (UNFCCC) in December 1997 has given increased momentum to CAEP's work in the emissions field. In 1998, the ICAO Assembly adopted a resolution calling on CAEP to study policy options to limit or reduce greenhouse gas emissions from civil aviation. The Committee is required to consider the findings of the IPCC special report and the requirements of the Kyoto Protocol, and to report back to the next session of the ICAO Assembly in 2001.

CAEP's work on emissions falls into three categories, namely technology and standards, operational measures, and market-based options.

Technology and standards

CAEP has been considering to what extent technology can help achieve reductions in emissions through improved engine or airframe design. The present ICAO standards for emissions certification of aircraft engines were originally intended to respond to concerns regarding air quality in the vicinity of airports. As a consequence, they establish limits for emissions of NO_x, carbon monoxide (CO), unburned hydrocarbons (HC) and smoke, for a reference landing and take-off (LTO) cycle below 915 metres of altitude (3000 feet). These limits are expressed in terms of mass of emissions per unit of engine thrust.

While the standards are based on an aircraft's LTO cycle, they also help limit emissions at altitude. Of particular relevance is the standard for NO_x, a precursor for ozone. At ground level ozone takes part in smog chemistry, while at altitude it is a greenhouse gas. The standard for NO_x was first adopted in 1981. It was made more stringent in 1993, when ICAO reduced the permitted levels by 20% for newly certificated engines, with a production cut-off on 31 December 1999. In April 1998, CAEP recommended a further tightening of about 16% on average for engines newly certificated from 31 December 2003, a measure adopted by the ICAO Council in February 1999.

CAEP is now carrying out assessments of technological advances, so that ICAO standards can be modified to specifically address greenhouse gas emissions. In particular, it is studying alternate emissions methodologies that will encompass all phases of flight (climb and cruise emissions as well as the LTO cycle). In addition to considering the types of emissions already covered by ICAO standards, the new methodologies will take into account the fuel efficiency and productivity of the whole aircraft, which would have a direct bearing on CO_2 emissions. CAEP will also follow developments in the characterization and measurement of other emissions, such as particulates that could be relevant to contrail production and additional cirrus cloud formation. This is a very complex task, requiring close cooperation with industry and scientific experts, and recommendations for new methodologies are not expected to be completed until 2001. Definition of relevant standards, if appropriate, would follow.

Operational measures

CAEP is considering to what extent operational measures, such as more direct routings, might help reduce the amount of emissions produced. Work is currently focused on two key deliverables (by January 2001):

- Quantification of the environmental benefits possible with the adoption and implementation of ICAO's satellite-based CNS/ATM (communications, navigation, surveillance/air traffic management) systems. This is a coordinated effort between the Federal Aviation Administration (United States) and the European Organization for Safety of Air Navigation B EUROCONTROL (29 European States). The study methodology, and an initial global assessment of the environmental benefits of CNS/ATM, have been completed. This initial study quantifies the emissions reductions to be achieved in the US and Europe, based on planned enhancements to the respective air traffic environments, and provides baseline assessments of the various ICAO regions on which to base future improvements. Next steps will be to work with ICAO's regional planning groups to help them incorporate environmental considerations into their CNS/ATM implementation plans, and to provide an assessment of those benefits.
- A draft guidance material for States and the wider aviation community on operational opportunities to reduce aircraft engine emissions. The goal of the document is to offer practical information to reduce aircraft engine emissions through changes in operational procedures and practices. The document incorporates a wide variety of inputs from airlines, airports and air traffic service providers to provide an end-to-end look at practices now in use to reduce emissions. It has sections on technology, maintenance, non-revenue flying, weight reduction, load factor, flight planning, airports, take-off, climb, cruise, descent and landing, infrastructure, etc. The next step will be to finalize the document and make it publicly available as an ICAO Circular.

Market-based options

CAEP is also identifying and evaluating the potential role of market-based options, including emission-related levies (charges and taxes), emissions trading and voluntary programmes, as a means of limiting greenhouse gas emissions. As the IPCC Special Report has indicated, several different emissions from aircraft engines play a role in climate change. However, this tends to complicate the design and evaluation of market-based options. It has therefore been decided to focus on CO_2 emissions only at this stage, while leaving open the possibility of accommodating other emissions later if appropriate.

While CAEP has traditionally adopted technology-based standards for controlling emissions, market-based options also offer a potentially cost-effective approach to achieving environmental objectives. However, their use raises a number of important economic, legal and administrative issues that must be fully evaluated.

CAEP has identified and begun to define a range of specific market-based options, including:

- a fuel tax, with revenue going to national treasuries;
- revenue-neutral charge based on aircraft efficiency, with higher charges on less fuel-efficient aircraft offset by lower charges on more fuel-efficient ones;
- an en-route emissions charge, with revenues recycled to the aviation sector;
- an open emissions trading system, in which emissions from all aviation sources (domestic and international) are treated identically to other emissions, and trading may take place between the aviation sector and other sectors;
- a closed emissions trading system, in which international aviation emissions may only be traded within the aviation sector, with a fixed cap;
- voluntary programmes, as well as hybrid options drawing on elements from each of the three approaches under consideration (levies, trading and voluntary programmes);

CAEP has also developed an evaluation framework that will allow transparent comparison of the strengths and weaknesses of these options. The results of this technical evaluation will be subject to a policy review by the next full meeting of the Committee (CAEP/5) in January 2001, and consideration by the ICAO Assembly.

Future meetings

The present CAEP work plan in both the noise and emissions fields is aimed towards CAEP/5. Thereafter, CAEP's recommendations will be reviewed by the Council of ICAO. Some aspects are also expected to be discussed at the 33rd ICAO Assembly in September/October 2001.

Plans are being made for a colloquium on environmental aspects of aviation, to be held in April 2001. This would provide for wide-ranging discussion of aviation environmental matters in the months leading up to the 33rd Assembly.

Notes

1. Resolution A32-8, the *Consolidated statement of continuing ICAO policies and practices related to environmental protection*, is accessible on the ICAO website (www.icao.int) under "Environmental Protection".
2. Council Regulation (EC) No. 925/1999 of 29 April 1999 on the registration and operation within the Community of certain types of civil subsonic jet aeroplanes which have been modified and recertificated as meeting the standards of Volume I, Part II, Chapter 3 of Annex 16 to the *Convention on International Civil Aviation*, third edition (July 1993).
3. Penner, Joyce E., David Lister, David J. Griggs, David J. Dokken and Mack McFarland (1999) *Aviation and the Global Atmosphere*, Cambridge University Press (available in both hardcover and paperback). Radiative forcing is a measure of the importance of a potential climate change mechanism. Positive values of radiative forcing imply a net warming, while negative values imply cooling. ◆

Le rail au service du développement durable : quel part du marché pour le fret ferroviaire en France ?

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Les tendances historiques

Le transport par chemin de fer a des qualités qui ne sont pas contestées, même par les lobbies de ses concurrents : il est économe en consommation d'espace, économe également car moindre consommateur d'énergie, énergie qui est largement électrique, il est donc peu polluant et surtout très peu producteur de gaz à effet de serre.

EURO/1000/pkm/tkm	Passagers		Fret	
	Route	Rail	Route	Rail
Accidents	35,1	0,9	11,5	0
Bruit	5,7	3,9	6,7	3,5
Pollution atmosphérique	17,3	4,9	37,4	4
Effet de serre	15,9	5,3	16,2	4,7
Total	74,6	15	71,8	12,2

Source : External costs of transport, INFRAS/IWW, mars 2000

De fait, en ne considérant que les émissions de CO_2, le contenu moyen en gramme de carbone d'une tkm de fret ferroviaire est de 3 grammes ; celui d'une tkm de fret routier (en considérant un poids lourd moyen supérieur à 3,5 tonnes et une charge moyenne de 6 tonnes) est estimé à 33 grammes. Sur le territoire français, le transport de fret par train est donc en moyenne 10 fois moins producteur de CO_2 que le transport routier. On peut donc affirmer sans crainte qu'il est globalement respectueux de l'environnement.

Sur un terrain différent, davantage sociétal, le transport ferroviaire est très sûr. En effet, l'ensemble du système de sécurité des grands réseaux européens est d'abord conçu pour le transport des personnes. Le transport des marchandises bénéficie de ce haut niveau puisque son exploitation est totalement intégrée dans celle des autres trains en cohabitant sur les mêmes lignes. Il en est de même du niveau de sécurité du transport des matières dangereuses qui, de ce fait, est très élevé. Sur le même registre social, les conditions de travail des personnels ferroviaires sont clairement définies et respectées, ce qui n'est pas nécessairement la règle pour tous les modes de transport.

Enfin, au plan économique, le fret ferroviaire sait être d'une grande efficacité et d'un coût raisonnable comparativement au transport par route. C'est d'autant plus vrai que les quantités à transporter sont importantes et que les lieux à desservir sont directement reliés aux réseaux ferroviaires grâce à des embranchements.

Souvent économiquement pertinent, pertinent également socialement et environnementalement, le mode ferroviaire peut à juste titre prétendre contribuer au développement durable.

Or, malgré ces atouts indéniables, le transport des marchandises par le rail est en déclin quasi permanent sur tous les réseaux d'Europe de l'Ouest, la France n'échappant pas à la tendance même si la part de marché du ferroviaire dans ce pays est encore comprise entre 20 et 25%. L'explication n'est pas très compliquée et éclairera sur les conditions d'un renouveau avec développement, en forte rupture de tendance.

L'analyse du déclin

La Société Nationale des Chemins de Fer Français (SNCF) , tout comme les autres grandes entreprises ferroviaires, souffre de deux handicaps principaux : son insuffisante capacité à s'adapter et le niveau des prix du marché.

La difficulté d'adaptation des chemins de fer est un sujet bien connu. Les économies nationales ont changé : les transports de matières premières et de pondéreux ont été supplantés par des besoins qui prennent une place de plus en plus intégrée et serrée au sein de chaînes de production ou de distribution dans l'esprit « juste à temps ». Or, le chemin de fer, moyen de transport très capitalistique aussi bien du point de vue des infrastructures que des matériels roulants, a besoin de temps pour adapter, d'une part son patrimoine, et d'autre part et plus généralement, sa production qui est largement imbriquée entre branches d'activité. Il appartient donc aux entreprises ferroviaires de réussir à mieux anticiper les besoins du marché pour être moins souvent en décalage, décalage qui s'apparente pour beaucoup à un cycle d'hystérésis.

La question du prix de marché est plus délicate, car elle relève beaucoup moins des seuls chemins de fer. Le transport routier est en effet devenu le mode dominant et c'est lui qui fixe les prix. Certes il est irremplaçable et le transport ferroviaire lui-même ne peut envisager de se passer de lui. Mais comme il ne fait payer à ses clients que la moitié environ de ce qu'il coûte à la collectivité, les conditions de concurrence sur le marché des transports conduisent à une situation préoccupante. Le résultat pour la SNCF est que celle-ci a beaucoup de mal à dégager des marges, qui sont pourtant les seules sources d'investissements indispensables à son développement. Mais plus généralement, il faut se demander comment infléchir une situation dans laquelle le prix du transport est si anormalement bas que la fonction "transport" sert de variable d'ajustement à bien des processus de production ou de distribution. Les transporteurs routiers et leurs personnels seraient les premiers bénéficiaires d'une telle inflexion en permettant de mieux respecter l'environnement ou de faire progresser les conditions de travail des personnels.

Une vision ambitieuse de l'avenir

Si le « laisser-faire » de ces dernières décennies, à la fois si pratique et en apparence si efficace, a finalement hypertrophié un transport routier devenu difficilement maîtrisable, le rééquilibrage demandera du courage et de la volonté.

L'ensemble des acteurs doit d'abord voir loin et viser haut. Quelle que soit la dénomination d'un tel exercice (prospective, schéma directeur,...), une vision à 30 ans (environ) est indispensable.

De fait, si le mode ferroviaire peut acheminer des quantités de fret considérables, il doit pour cela disposer, sur ses axes majeurs, d'infrastructures qui lui soient quasiment dédiées. On y gagnerait là l'un des atouts majeurs de l'efficacité du TGV : pouvoir engager des convois aux caractéristiques quasiment identiques les uns derrière les autres à intervalles réguliers en optimisant le débit des lignes.

L'émergence d'un réseau Fret, sur lequel les convois devront pouvoir parcourir de grandes distances, est donc à préparer. Ce réseau contournera sys-

thématiquement tous les nœuds ferroviaires situés en zones urbaines qui sont de plus en plus saturés par les dessertes grandes lignes (TGV) et régionales. Entre ces pôles, il s'appuiera largement sur des lignes existantes exploitées actuellement ou non, mais nécessitera parfois la construction de nouveaux tronçons aux caractéristiques adaptées.

Grâce à une telle ossature de quelques milliers de kilomètres bien connectée au réseau existant, et à condition qu'un effort comparable ait été fait dans les pays voisins, il est parfaitement envisageable de multiplier par dix (en tonnes km) le trafic Fret sur le territoire français.

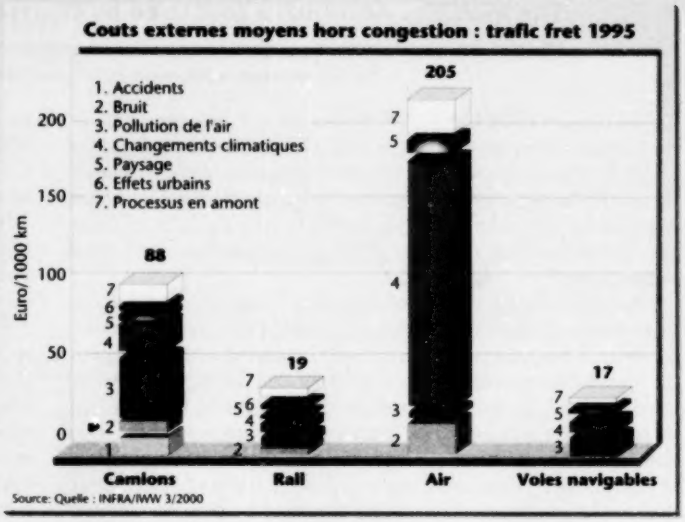
Comment progresser fortement dans la durée ?

C'est sans doute là qu'est la difficulté majeure. En effet, chacun des acteurs doit faire évoluer durablement son organisation et ses performances et engager des financements non négligeables.

Le gouvernement français s'est déjà exprimé par la voix du Ministre chargé des Transports sur sa volonté politique de développer le Fret ferroviaire. Il lui faudra piloter la démarche prospective et soutenir les acteurs publics, Réseau Ferré de France (RFF) et SNCF, dans leur progression conjointe et solidaire . Il lui faudra aussi faire émerger les projets d'infrastructures nouvelles, souvent aux limites des agglomérations denses, et les faire accepter par les populations riveraines. Ces projets devront constituer des étapes fonctionnelles permettant des développements associés de trafic répondant aux besoins. Il lui faudra également accompagner par des mesures adaptées la progression des trafics qui occasionnera par nature davantage de nuisances.

Les collectivités territoriales associées dès l'amont aux travaux prospectifs dans le cadre des contrats de plan qui lient l'Etat et les régions pour la période 2000-2006, participeront également aux études et à la réalisation de projets afin d'obtenir une cohérence entre les politiques nationales et locales de transport au sein des schémas de services. Elles devront, comme elle le font déjà très efficacement pour les projets de TGV ou de liaison rapide, jouer le rôle de relais entre les populations et les acteurs nationaux pour trouver les solutions les plus efficientes et les plus acceptables.

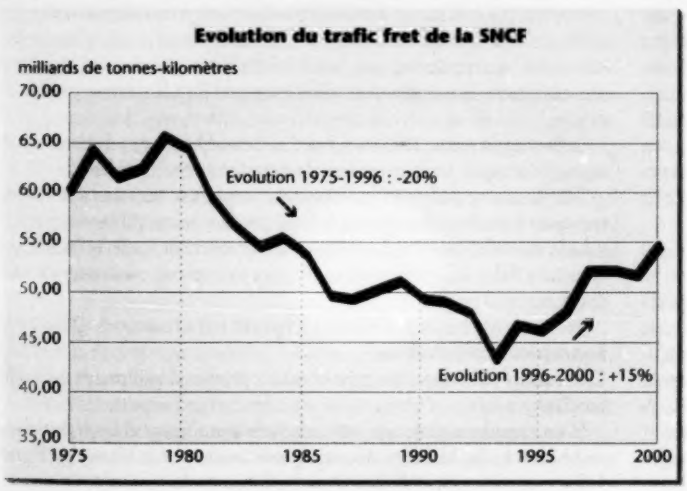
RFF devra étudier et engager les projets d'investissements permettant au transporteur de suivre le rythme de son développement.



La SNCF devra progresser encore dans la qualité de la production des services qu'elle offre à ses clients. C'est le sens de la création récente du Centre National des Opérations qui vise à améliorer ses fondamentaux : sécurité, vitesse, ponctualité. Elle développe également un suivi des circulations grâce au GPS pour informer en temps réel ses clients de la position de leurs acheminements. Des investissements substantiels ont par ailleurs été engagés avec le lancement de la première tranche d'un programme de commandes de 600 locomotives Fret. Il appartiendra à l'entreprise de dégager les moyens humains suffisants pour assurer la traction des trains de Fret sans conflit d'intérêt avec ses autres activités.

Enfin, les chargeurs et les industriels clients, présents et à venir, du transport ferroviaire devront accepter de poursuivre en l'amplifiant le partenariat actif qu'elles ont avec la SNCF. En effet, le mode ferroviaire, qui présente de forts avantages environnementaux, porte avec ces avantages d'une part une certaine inertie liée aux coûts d'investissement et aux procédés de mise en oeuvre et supporte d'autre part des coûts totaux qui intègrent une large part des coûts externes qu'il engendre, contrairement aux transports routiers qui sont loin d'intégrer dans leurs coûts les effets externes qu'ils génèrent pour la collectivité.

Ces deux particularités imposent un partenariat loyal dans lequel chaque acteur assume ses responsabilités tout en œuvrant pour des objectifs partagés.



En conclusion : faut-il être optimiste ?

Le rédacteur de ces lignes n'engage que lui-même en répondant sans hésitation par l'affirmative. La nécessité de maîtriser le plus rapidement possible les émissions de gaz à effet de serre, qui conditionne la stabilisation du réchauffement de la planète, ainsi que la prise en considération par les citoyens de la qualité environnementale des produits et services qu'ils consomment, sont des éléments qui justifient le rééquilibrage évoqué et l'investissement public qu'il sous-tend. Quant à la SNCF, elle doit poursuivre l'amélioration de sa qualité au service de ses clients.

The Mobility Account: a tool used by Deutsche Bahn AG and WWF-Deutschland

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On the occasion of the October 1999 UN Climate Conference in Bonn, the German environmental organisation WWF-Deutschland and the Deutsche Bahn (German railways) developed a study called *Mobility Account for Passenger and Goods Transport – A comparative look at transport systems in Germany.* The aim of this study is to compare the travel times, costs and environmental impacts of railways, cars, airplanes and inland water transport.

The Mobility Account is methodologically enhanced over earlier studies to increase its transparency and objectivity in comparing various means of transport. While earlier studies have mostly been based on average figures, the Mobility Account illustrates the environmental impacts of individual travel situations. Most common reasons for short- or long-haul trips (e.g. shopping, business, holidays) are selected and analyzed in order to allow a profound and comprehensive understanding, from an environmental point of view, of the weak and strong points of different transport modes. Using this knowledge, a software tool has been developed that helps the customer choose the best mode.

The fact that rail is comparatively environment-friendly is attributable to the advantages inherent in the wheel/rail concept: low steel-on-steel rolling friction; the track's guidance function, which allows running long trains; and grouping of consignments, which helps ensure efficiency. However, customers rarely opt for rail travel solely on account of its environmental benefits. Their choice is influenced first and foremost by price, time and service. Environmental protection is an additional argument that may tilt the scales in favour of rail – if the service provided is an attractive and roughly comparable alternative to that of rival modes.

More important, drawing the attention of existing customers to rail's environmental advantages may consolidate their decision. From the point of view of advertising psychology, this type of positive confirmation is one of the fundamental rules concerning customer loyalty. The automotive industry vaunts its three-litre car and the emission standards with which new vehicles now comply, which represent a decrease in exhaust emissions of up to >90% compared with the past. German airlines take out full-page advertisements to plug their fleet's fuel consumption rate of 3.7 litres per 100 passenger-kilometres, also emphasizing that they are seeking to boost efficiency wherever possible. Railways cannot afford to rest on their laurels, relying on their historical image as an environmentally sound transport mode, as zero-emission vehicles and low-noise lorries are trumpeted as an alternative. They must learn to make their environmental advantages known to the outside world and firmly establish in public opinion their image as a resource-efficient transport mode.

Transport is considered one of the primary man-made causes of the greenhouse effect, probably the most acute environmental problem to be faced in coming decades. In the Federal Republic of Germany, transport's share in energy-related emissions of the greenhouse gas carbon dioxide (CO_2) increased from 16% in 1990 to 20% in 1998. International air traffic emissions are not yet included in those statistics. Hence, transport accounts for a substantial and indeed growing proportion of German CO_2 emissions, more than, say, private households or manufacturing industry.[1,2] Such developments seriously threaten attainment of the climate protection targets, agreed in Kyoto, that require Germany to cut production of greenhouse gases by 21% by 2008 taking 1990 as the reference year.

There is vast potential for reducing emissions from transport:

- Every tonne of transported goods transferred from road to rail in Germany reduces environmental pollution by 8.1 kg CO_2 per 100 km.[3]
- Every person switching from car to train reduces environmental pollution by 10.4 kg of CO_2 per 100 km.[4]

All in all, CO_2 emissions could rapidly be slashed by roughly 75% through switching from road and air to rail. Such potential, which can be realized through tapping into the rail system's existing energy efficiency, underscores its social utility. This fact needs to be disseminated at regular intervals in political spheres, to bring home the need for an active railway policy.

The Mobility Account clearly demonstrates rail's environmental advantages

For the reasons outlined above, it is crucial that rail maintain and amplify its competitive advantage in terms of energy efficiency. And it is at least as vital that methods be developed to publicize this competitive advantage beyond the rail sector in a proactive and convincing manner.

The Mobility Account,[5] published in cooperation with the German branch of the World Wide Fund for Nature (WWF-Deutschland), is a step in the right direction. It is a precise decision-making aid for travellers attuned to environmental concerns. Moreover, it clearly demonstrates that rail is not only the most environmentally compatible transport mode, but in many cases also the most cost-effective and fastest. The fact that work on the actual substance of the report was steered by an independent German research body, the Institut für Energie- und Umweltforschung (IFEU) (Institute for Energy and Environment Research) in Heidelberg, lends this two-part publication the requisite credibility and weight.

Brochure explaining how transport modes are compared

The "Mobilitäts-Bilanz" (Mobility Account) brochure provides an overview of the environmental impacts of various transport modes using real-life examples of short- and long-haul trips for business, shopping and holidays. The criteria examined include energy consumption and emissions of air pollutants and climate gases, as well as expenditure and the time required for a given travel option.

By distinguishing between the different reasons for making a journey, it is possible to explain the relevant factors used to compare transport modes. Hence, when a car takes a family of four on holiday, use of capacity is four times greater than when a private car is driven by a single occupant on a business trip. Moreover, cars used for business trips tend to have more powerful engines. When the environmental impacts of two transport modes are compared, the conclusion drawn differs if the impact is calculated in terms of the number of people transported. The same is true for rail, where extensive use of capacity during rush hours means the environmental indicators are much more favourable than when measured for a late evening rail journey.

In the freight sector, rail is compared with road haulage and inland waterways. Once again, its environmental advantages stand out clearly.

The brochure makes a fundamental comparison between the various transport systems with respect to safety, comfort, noise, infrastructure and vehicle manufacture. It also outlines the commitment made by each of the Deutsche Bahn AG joint stock companies to improve even more on rail's environmental record.

Example: "commuters"

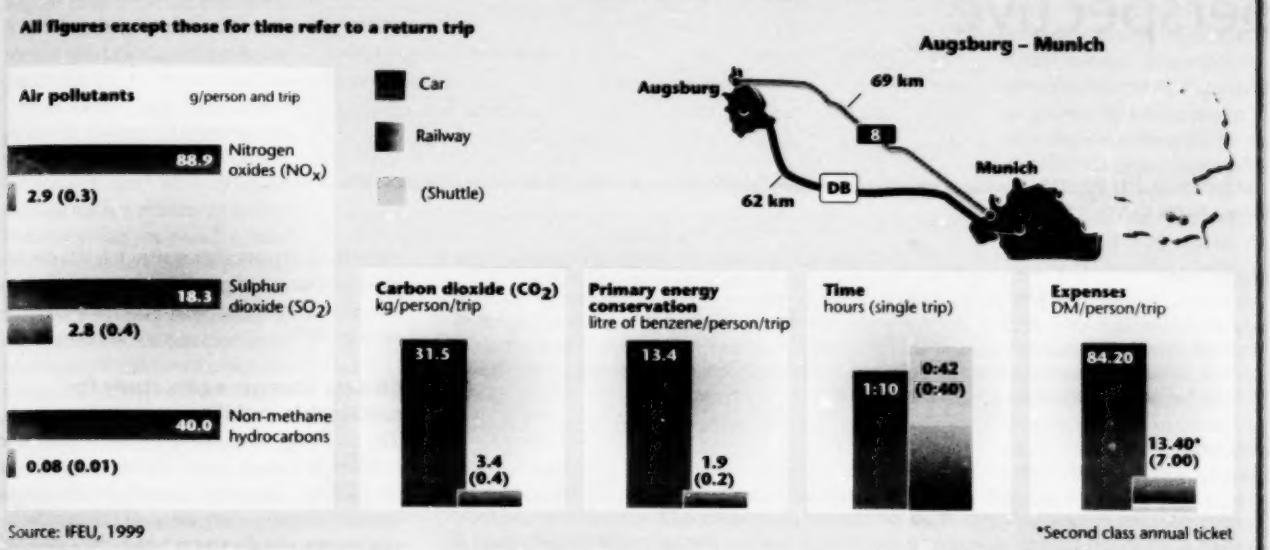
One example illustrates the type of results produced and presented in the brochure.

If we consider a passenger who regularly commutes between Augsburg and Munich, the Mobility Account produces the results shown in Figure 1. Expenses are principally based on the full costs of a passenger car according to the declarations of the Allgemeine Deutsche Automobil Club ADAC (General German Automotive Club) published in its June 1999 car catalogue. The costs of the train journey are calculated based on the price of a second class annual ticket for this route and the respective public transport systems in Augsburg and Munich.

The journey takes about 80 minutes overall, of which 42 minutes on the CityExpress train and 20 minutes for changing transport mode and for tram use at each end (i.e. in Augsburg and Munich). It takes about 70 minutes by car.

The train's high occupancy rate (70%) is one of the reasons our commuter

Figure 1
Mobility Account results for commuting between Augsburg and Munich



requires six times less energy to travel by rail than by road. This, by the way, presents a clear challenge to the railways to press ahead with respect to the occupancy rate, and not only for economic reasons. The train comes off even more favourably when CO_2 and other emissions are compared. This is due to use of electric energy for train operation being cleaner than benzene combustion in a modern passenger car with catalytic converter and lambda sound.

The train's ecologically superior mobility chain helps the commuter save about 64 German marks (DM) on a return trip.

A software programme for drawing up individual environmental impact assessments

In conjunction with the brochure, a software programme, "Reisen und Umwelt in Deutschland 1999" (Travel and Environment in Germany 1999) is available for planning individual passenger trips. It enables users to generate their own environmental impact assessments for over 1600 connections throughout Germany using their home computers. In this way they can find out, for example, exactly how many litres of petrol (gasoline) they could save on their next trip and how many kilograms of climate-threatening CO_2 would not be pumped into the atmosphere if they opted for the train. Inspiration can be drawn from the rich store of pre-recorded travel examples.

Mobility Accounts for freight transport need more work

PR efforts to date have tended to focus on passenger traffic, with the aim of helping a broad public choose the best transport mode.

When it comes to freight traffic, the target group is completely different, with and highly specific expectations. An impact assessment instrument would be useful to help manufacturing industry and business evaluate and optimize their logistics precepts from an environmental perspective. As globalization gathers force, bringing with it growing cross-border trade flows, transport and its environmental impacts are becoming increasingly important factors in corporate environmental assessments. In some manufacturing sectors, transport contributes more than 25% of companies' total energy consumption and up to 80% of emissions of relevant pollutants.[6]

A uniform assessment tool could help standardize the often patchy and outdated data used for freight traffic and prepare it for practical application, thereby readying it for use in transport assessments compiled during corporate environmental audits. This type of practical tool could be an invaluable aid to many companies in light of revision of the EU's eco-audit regulation (EMAS II), which stipulates that transport must feature in corporate eco-audits.

The first steps in this direction are being taken by a project group comprising five national railways (SJ, Sweden; SBB/CFF, Switzerland; FS, Italy; SNCF, France; DB, Germany). However, producing a comprehensive, widely accepted ecologistics assessment tool that can be used worldwide will require substantial financial and staff resources, as well as sufficient involvement of all competitors in compiling the content. Such an endeavour cannot be accomplished by the railways alone. The logical solution would be to set up a European research project, endowed with the requisite EU funding.

Notes

1. DIW (1999) CO_2-Emissionen in Deutschland: Weiterhin vom Zielpfad entfernt (CO_2 Emissions in Germany: Still off track). In: *Wochenbericht des DIW* 6/99.
2. DIW (2000) CO_2-Emissionen im Jahre 1999. Rückgang nicht überschätzen (CO_2 Emissions in 1999: Don't overestimate the drop). In: *Wochenbericht des DIW* 6/00.
3. DIW (1999) Energieverbrauch im Verkehr in Deutschland. Verringerung der Wachstumsraten in den neunziger Jahren (Energy consumption in the German Transport Sector: Slowing down of growth rates in the 90s. In: *Wochenbericht des DIW* 10/99.
4. Prognos AG (1995) *Bedeutung und Umweltwirkungen von Schienen- und Luftverkehr in Deutschland* (The Significance and Environmental Impact of Rail and Air in Germany).
5. Deutsche Bahn AG (1999) *Mobilitäts-Bilanz für Personen und Güter. Die Verkehrssysteme im Vergleich. Eine Initiative von WWF-Deutschland und Deutscher Bahn AG* (Mobility Account for Passenger and Goods Transport – A comparative look at transport systems in Germany. A joint WWF-Deutschland and Deutsche Bahn AG initiative). German language publication that can be ordered free of charge from: *Bahn-Umwelt-Zentrum@bku.db.de.*
6. Institut für Energie- und Umweltforschung (1999) *Verkehr im Umweltmanagement. Anleitung zur betrieblichen Erfassung verkehrsbedingter Umweltwirkungen. Ein Leitfaden erstellt im Auftrag des Umweltbundesamtes Berlin* (Transport and Eco-management. Instructions for surveying a company's transport-related environmental impact.) Commissioned by the Federal Environment Bureau, Berlin.

Deutsche Bahn internet site: http://www. bahn.de

Sustainable mobility: a government perspective

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Summary
Addressing transportation's environmental impacts requires a holistic approach. Such an approach considers all aspects of the transportation system, in order to stimulate integrated, mutually reinforcing actions aimed at changing behaviour, technology and infrastructure. A key role for government (illustrated by Canada's national climate change process in the transport sector) is provision of a supportive framework.

Résumé
Aborder le problème de l'impact des transports sur l'environnement exige une approche holistique, qui prend en compte tous les aspects du réseau de transport, de manière à susciter des actions intégrées complémentaires et qui permettent de modifier les comportements, la technologie et les infrastructures. Comme l'a montré le processus engagé par le Canada dans le secteur des transports pour lutter contre le changement climatique, les gouvernements ont ici un rôle clé à jouer : mettre en place un cadre de nature à soutenir ces actions.

Resumen
Para afrontar el impacto medioambiental del transporte, es preciso un enfoque integral, que considere todos los aspectos del asunto, para estimular iniciativas coordinadas y sinérgicas, que permitan cambiar la conducta, la tecnología y la infraestructura. El gobierno debe desempeñar un papel clave, mediante la creación de una estructura de apoyo (como en el caso del proceso nacional de cambio climático en el sector del transporte, efectuado en Canadá).

In a country as vast as Canada, transportation has an impact on every aspect of life and business. People make billions of trips each year travelling for work, recreation, medical care and other diverse reasons. Transportation also plays a vital role in Canada's position as a trading nation. North-south transportation links with the United States have grown increasingly important with the signing of the North American Free Trade Agreement (NAFTA). Canada and the United States exchange nearly C$ 1.5 billion every day in goods and services. Transportation is also fundamental to tourism. It accounted for 40% of the C$ 44 billion spent in 1997 in this industry in Canada.

Canada's well developed transportation system represents a large investment in infrastructure, vehicles, equipment and the fuel distribution network. The planning and managing of this system is complex. Four levels of government – federal, provincial/territorial, regional and municipal – have jurisdiction and regulatory authority over different aspects of the system. Making changes to improve the transportation system's sustainability requires cooperation and agreement among governments.

In recent years, the role of the federal transportation department has evolved significantly away from direct operation of transportation facilities and services. It now has a more "arm's length" role as landlord, overseer, regulator and policy-maker. This change in the nature of its responsibilities has important implications for how the department carries out its mandate, and how it approaches sustainable transportation.

Current trends are for continued growth in passenger and freight activity, particularly in the air and road transportation modes. Passenger transportation is dominated by private light duty vehicles (cars, vans and light trucks), which account for 87% of all passenger-kilometres travelled. Although energy efficiency is forecast to improve 0.7% annually until 2020, this progress is being overwhelmed by the increased use and number of vehicles. **Figure 1** illustrates these trends for light duty vehicles in Canada.

Overall freight transport activity, as measured in tonne-kilometres, is forecast to increase by 60% between 1990 and 2020, with a 94% increase in trucking activity and 104% increase in air freight activity. These growth trends are shown by mode in **Figure 2**.

This growth will contribute to a variety of environmental pressures in Canada, ranging from air pollution, climate change, ozone depletion and acid rain, to land, water and groundwater contamination, depletion of non-renewable resources, disruption of habitat, and congestion and urban sprawl. In 1995, transportation was responsible for 52% of all nitrogen oxide (NO_x) emissions, 40% of those of carbon monoxide (CO), 20% of those of volatile organic compounds (VOCs) and 5% of those of particulate matter. It is also the single largest source of greenhouse gas emissions in Canada – accounting for 25% of national emissions in 1997.

Climate change: a case study for sustainable mobility

The challenge of working towards sustainable mobility in Canada is well illustrated by climate change issue. Reducing Canada's greenhouse gas emissions engages every aspect of the transportation system, and the way in which the individual components of the system interact with each other. **Figure 3** illustrates the source of Canadian greenhouse gas emissions by mode. Emissions are directly proportionate to the level of transportation activity in each mode and the amount of fossil fuel consumed to support this activity. In many cases the solutions that can be found to reduce transportation greenhouse gas emissions also offer important benefits with respect to other transportation issues such as smog, congestion, noise, land use and urban sprawl.

There are four basic approaches to reducing transportation greenhouse gas emissions, each of which presents economic, technological, social and political challenges:

- limiting the growth of transport activity, potentially restricting mobility or the flow of goods in the economy;
- improving the overall efficiency of the transportation system by encouraging use of less energy-intensive modes, improving the interface between individual modes to reduce congestion, and encouraging multi-modal transportation;
- improving energy efficiency within each mode through the introduction of new technologies, operating practices and improved infrastructure; and
- reducing the carbon content of the transportation fuels used through new production technologies, changes in vehicles and engines, and new fuelling infrastructure.

Challenges facing decision-makers

Decision-makers face some significant challenges in assessing the options under each of these basic approaches. Transportation is a derived demand. **Figure 4** shows how the demand for transportation has grown with the economy in Canada. Because the Canadian transportation sector is almost totally fossil fuel based, the sector's greenhouse gas emissions increase with economic growth. By 2020, Canada's economy is forecast to

be 70% larger than in 1995. Reducing greenhouse gas emissions from transportation will require us to break the traditional link between growth in demand for transportation and greenhouse gas emissions.

In assessing changes to the transportation system, it is important to consider potential impacts on the competitiveness of individual transportation modes, as well as impacts within the overall economy. Canada's economy and transportation system are highly integrated within a North American framework. Its transportation options must take into account the United States' response on climate change.

Commercializing and deploying new technologies takes time. Some equipment, such as airplanes, ships or rail cars, stays in service for many years, making rapid changes in the capital stock difficult without policy or market changes. Under current conditions and markets, it can take 20-30 years to turn over the current fleet of millions of vehicles. Changing urban infrastructure to favour less energy-intensive transportation will require long-term change.

Canada's transportation system reflects the large area and relatively dispersed population of the country. Regional transportation systems have developed differently, depending on geography, climate, the regional economy, and the location of the population. Emission reduction strategies have to be flexible enough to accommodate regional differences and local circumstances.

Mobility is a key element of Canada's standard of living. It is important to understand that various options will affect urban and rural communities differently. Choices with respect to land use, urban design, roads and public transportation have a profound effect on urban communities. In rural areas, distances to services are greater and there are fewer alternatives to the private automobile. Changes to transportation behaviour will only happen if the public is engaged, understands the issues, has high-quality alternatives to turn to, and can perceive a range of benefits in addition to reduced fuel use.

Figure 1
Growth in number and use of light-duty vehicles in Canada

	1990	1995	2000	2010	2020
Automobiles (millions)	11.10	10.31	9.37	9.72	12
Average distance per vehicle (kms)	16,738	18,786	19,817	19,839	19,584
Light trucks (millions)	3.45	4.34	5.16	6.81	8.61
Average distance per vehicle (kms)	23,167	22,166	22,209	21,612	21,181
Total vehicle-kms travelled (billions)	265.72	289.78	300.20	339.92	407.86

Figure 2
Freight transport activity by mode in Canada (million tonne-kilometres)

	1990	1995	2010	2020	Total change 1990-2020
Truck	149,000.0	180,000.0	240,000.0	289,000.0	94%
Air	544.5	584.8	859.5	1111.0	104%
Rail	250,100.0	282,400.0	342,800.0	390,000.0	56%
Marine	50,900.0	42,500.0	42,500.0	42,500.0	-16.5%
Total	450,544.5	505,484.8	626,159.5	722,611.0	60%

The Transportation Climate Change Table

In December 1997, the Prime Minister of Canada and the Premiers of the ten provinces initiated an innovative two-year national process to develop a climate change strategy that could respond to the recently negotiated Kyoto Protocol on climate change. Under this process, led by Ministers of Energy and Environment, a series of working groups (called "issue tables") were set up to involve experts from across the country in analyzing options for reducing Canada's greenhouse gas emissions.

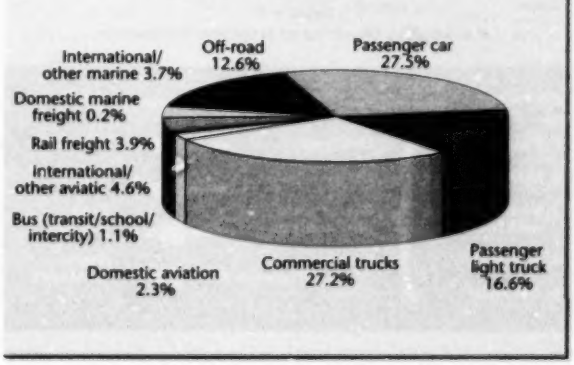
As part of this process, the federal, provincial and territorial Ministers of Transportation jointly sponsored the Transportation Climate Change Table. This Table was co-chaired by one government official (Assistant Deputy Minister, Transport Canada) and one non-government official (Executive Director, Pollution Probe – a Canadian environmental group). The 25 members of the Table were drawn from every aspect of the transportation system: all freight modes (road, rail, marine, air), all passenger modes (bus, rail, road, air) conventional and alternative transportation fuels, vehicles and equipment manufacturing, shippers, consumers, federal, provincial and municipal governments, environmental and other non-governmental organizations.

The mandate of the Table was to identify and analyze a range of potential measures to reduce greenhouse gas emissions from transportation, including the impacts of measures, their associated costs and benefits, during the Kyoto period (2008-2010) and beyond to 2020. The Table was asked to build an incremental package of measures that would achieve progressively greater reductions in emissions within the transport sector until reaching, or if possible exceeding, a 6% reduction from 1990 levels (i.e. Canada's national reduction target under the Kyoto Protocol). It is important to note that no sector was actually assigned a reduction target. The objective was to identify the most cost-effective options across all sectors of the economy.

The Table met every month or so for a period of 18 months. Table members began by producing a background paper to establish a common understanding of the transport sector, its emissions, and the broad options available to reduce these emissions. The Table then commissioned 24 analytical studies to identify and analyze specific measures in four categories: Road Vehicle Technology and Fuels, Freight Transportation (all modes) Passenger Transportation (urban and inter-city) and Road Infrastructure.

Through this analysis, the Table identified and studied roughly 120 potential measures. Using a number of criteria – including cost-effectiveness, ease of implementation, competitiveness impacts, confidence in the analysis and data, and potential for public acceptance – the Table ranked these measures into four categories (**Figure 5**). While it is not possible to convey all of the Table's findings here, the following gives a sense of the type of measures which the Table found to be "most promising' and 'promising'.

Figure 3
Source of transportation GHG emissions in Canada (1997)



Passenger transportation

The Table identified a range strategies to reduce greenhouse gas emissions from passenger activity in urban centres. Measures such as tax-free transit benefits, telecommuting, car/ride sharing, and driver education could be combined to form an effective strategy for voluntary employee trip reduction programmes. Significant enhancements to urban transit service through improvements in pricing, service and infrastructure were seen as fundamental to reducing private vehicle use. The Table combined support for investments in transit, bicycle and pedestrian infrastructure with disincentives for car use through higher parking charges in the three largest Canadian cities.

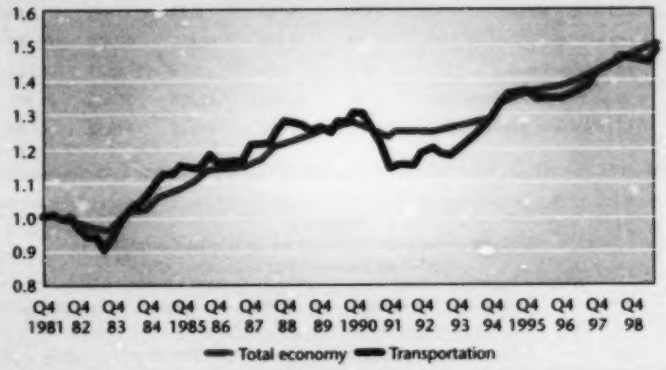
Road infrastructure

The Table focused on three key strategies for changing the way we build, maintain and use our roads and highways:

- enforcing existing highway speed limits, as vehicle fuel economy declines significantly above 90 kilometres per hour;
- using Intelligent Transportation Systems (ITS) applications for traffic signalization, traveller information and incident management, in order to achieve an overall improvement in traffic flow; and

◆ undertaking more frequent resurfacing of the national highway system, and increasing the use of High Occupancy Vehicle (HOV) lanes.

Figure 4
Transportation and economic activity seasonally adjusted quarterly GDP, 1981-1988
(Index, 1Q/1981=100)



Road vehicles and fuels

The Table felt that the greatest potential for reducing greenhouse gas emissions from vehicles and fuels would come from working with industry and the United States to achieve a 25% targeted improvement in the fuel consumption of new cars and light trucks by 2010. The Table also saw promise in supporting expansion of ethanol production for blending in gasoline, and incentives for alternative fuels in niche markets in major urban centres and in fleets.

Freight transportation

The Table identified a range of new truck technologies (e.g. advanced lubricants, speed control, load matching services, advanced tires) that hold promise for improving fuel efficiency within this mode. The Table also favoured an increase in the Capital Cost Allowance for rail equipment, voluntary codes of practice for the freight modes, and better truck driver training and operating practices. It examined options to shift freight transportation to less energy-intensive modes (rail and marine), but found that the specific options evaluated generated only small reductions at considerable cost. It was acknowledged that data in this area are weak, and the analysis is viewed as preliminary.

As part of its work, the Table also studied the use of market mechanisms such as parking charges, road pricing and fuel taxes to better reflect the full cost of different transportation services, and to encourage their most efficient use. In general, the Table felt there were significant design and analytical issues to be addressed for both urban road pricing and widespread urban parking charges, as well as considerable public resistance. These measures were therefore categorized as "Less Promising" in the Options Paper, even though their reduction potential was recognized.

Several fuel tax models were analyzed, but Table members did not reach a consensus on the use of these taxes as a measure to reduce greenhouse gas emissions. **Figure 6** is a summary of issues raised by the Table. A key lesson learned from the fuel tax scenarios was that Canadians place a high value on current transportation behaviour. Fuel prices would have to more than double in Canada if fuel tax increases were to be used as a single, stand-alone tool to reach the Kyoto target in the transport sector.

The Table's work represents a comprehensive but initial look at the costs and benefits of different options to reduce greenhouse gas emissions in the transport sector. **Figure 7** summarizes the potential greenhouse gas reductions from the "most promising" and "promising" measures identified by the Table. The Table's report was not intended to provide a prescription for implementation of the measures. It was recognized that many measures require more detailed analysis, design and consultation, including analysis by individual jurisdictions.

This message was reinforced during a series of eight workshops held across Canada to gather input from a broader range of stakeholders on the impacts and effectiveness of the measures in the Table's Options Paper. The Table's work was widely seen as a good first step, and a solid foundation for action. But there was a clear message that climate change measures must be assessed in the broader context of sustainable transportation and community development, and that there are areas that require further development.

Canada's National Implementation Strategy on Climate Change: the transportation component

The two-year national climate change process has produced Canada's National Implementation Strategy on Climate Change, which was released in October 2000. As part of this strategy, Canada's federal, provincial and territorial governments have agreed to develop a series of national business plans outlining concrete actions that they will take in all sectors of the economy to respond to climate change – individually, in partnership and collectively. These business plans will cover a three-year planning horizon and will be updated annually. The first national business plan for 2001-2003 was released by Ministers of Energy and the Environment in October.

The Government of Canada's contribution to the first national business plan was announced on 6 October 2000 in *Action Plan 2000 on Climate Change*. This comprehensive package of measures includes a commitment to spend up to C$ 500 million over the next five years on new measures to reduce greenhouse gas emissions. This builds upon the C$ 625 million announced in the 2000 budget for climate-related initiatives.

Transportation is a substantial component of *Action Plan 2000*. It is based on four key transportation objectives:

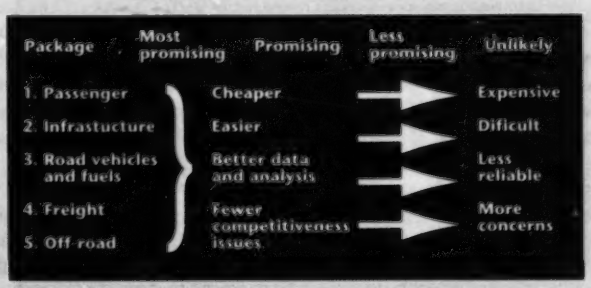
- ◆ improving urban transportation;
- ◆ improving new vehicle efficiency;
- ◆ increasing the use of less greenhouse gas intensive fuels; and
- ◆ increasing the efficiency of our freight system.

The five new transportation programmes included in the *Action Plan 2000* focus on initiatives that can produce cost-effective greenhouse gas reductions in 2010, offer clean air benefits for urban centres, have minimal competitiveness implications, have good public acceptance, support the take-up of new technologies, and improve the efficiency of the transportation system. The following is a brief description of these initiatives:

Urban transportation

Building on the Transportation Table's work, the federal government will work in partnership with provinces and municipalities to demonstrate the best urban transportation technologies and strategies to reduce greenhouse gas emissions. Four or five model "showcases" will be selected through a competitive process to demonstrate and evaluate a range of urban transportation options appropriate to local communities, including strategies to reduce use of cars and to shift passengers towards the less greenhouse-gas intensive travel alternatives. The results of the showcases will lay a foundation for the take-up of successful strategies in cities across Canada by 2010.

Figure 5
Packaging the transportation measures



New vehicle fuel efficiency

The government will work with the automobile industry and the United States to achieve new vehicle fuel efficiency targets by 2010. The objective will be to phase in a significant volun-

tary improvement in new vehicle fuel efficiency across Canada and the United States starting in 2004. This will be supported by increased new vehicle testing to confirm fuel consumption performance and remove potential safety barriers, and by a consumer education campaign to increase understanding of the importance of purchasing clean and efficient vehicles, as well as good driving habits and maintenance practices.

Fuels

The government will work with provinces and stakeholders to achieve a targeted increase in Canada's current ethanol production capacity of 750 million litres, which is triple our current capacity. This could enable as much as 25% of Canada's total gasoline supply to contain 10% ethanol (from biomass such as plant fibre, corn and other grains), a blend that can readily be used in all cars and that represents a lower greenhouse gas intensive fuel alternative.

Fuel cell vehicles

The government will establish a partnership with fuel cell suppliers, fuel providers, the automobile industry and interested provincial governments to encourage the acceptance and uptake of fuel cell vehicles in Canada. The partnership will work on a cost-shared basis to demonstrate and deploy hydrogen and other fueling infrastructure, and to address regulatory barriers to the increased use of fuel-cell vehicles.

Freight transportation

The government will develop partnerships and voluntary agreements within each freight mode to encourage the take-up of cost-effective practices and technologies that were identified by the Transportation Table.

These five transportation measures were carefully developed to strike a balance between our technology, behavioural change and infrastructure needs. Although promising vehicle and fuel technologies exist, technology can only get us part of the way towards our goal. The emphasis on pilot projects and demonstration reflects the Transportation Table's conclusion that many measures in this sector need further assessment before launching into full-scale implementation. The measures clearly recognize that we need to build partnerships with the many diverse players that affect transportation: industry, municipalities, provinces, and (perhaps most importantly) the consumer.

What we learned from the Transportation Table process

The Transportation Table process provides some useful insights for decision-makers. Whereas previous climate change initiatives have focused on specific elements of transportation, this is the first time a holistic analysis has been undertaken to analyze the costs and benefits of options across the entire transportation system. Significant equity has been built up, in terms of both our knowledge and the engagement of government, industry and other stakeholders in climate change issues.

Figure 6
Summary of Table views on fuel tax measures

Rationale for fuel tax

- Real gas prices are at late 1970s levels, limiting significant use of alternative fuels.
- No economic incentive for consumers; fuel efficiency is a low priority for vehicles.
- Prices reinforce technology. No price signal means little take up; manufacturers won't produce.
- Sustained higher prices reduce travel distance and promote shifts to other modes.
- Supports a move to full-cost pricing and targets GHG emissions.
- Source of funding for transit, incentives, or more efficient infrastructure.

Concerns about fuel tax

- Diesel taxes would cause competitiveness issues for trucking.
- Response based on elasticity assumptions. Some feel overly optimistic at lower levels.
- Impacts on transportation costs throughout the economy and on competitiveness with US.
- Impacts on tourism.
- Equity issues. Rural areas have fewer options. Harder on lower income earners.
- Cross-border shopping if price difference is too large.
- Lack of public support unless dedicated to improvements in transportation

Much can be learned from the process itself about to draw the many diverse players in the transportation system into the decision-making process. The process highlighted the importance of shared analytical work among transportation stakeholders – work that is planned, conducted and reviewed together. The 24 analytical studies conducted by the Table provided a critical opportunity to move towards a more shared understanding of complex, and often controversial, transportation issues.

The process also illustrated the importance of allowing sufficient time for new relationships to form across the transportation system, and for equity to be invested in the process. For the Table, this was achieved slowly over a two-year period. Although it has now formally disbanded, with its mandate complete, a solid foundation has been laid for implementing actions under the national business plan.

The Table's work greatly increased our base of knowledge concerning the costs and benefits of various opportunities to reduce transportation greenhouse gas emissions. It demonstrated that there are options that can help us achieve multiple transportation goals: climate change, smog reduction, congestion and efficiency. The Table also highlighted a number of areas where data on transportation is limited, and recommended the development of a national strategy to improve its quality. Further analysis was recommended to fill gaps in the Table's work, and much of this work has been undertaken or is underway.

Why do we need an integrated approach?

Perhaps the most important conclusion that can be drawn from the Table's work is that an integrated framework is needed to address climate change in the transport sector. There is no technology fix within the Kyoto timeframe. We need a mix of technology, behaviour change and infrastructure investment if we are serious about reducing emissions.

The measures identified by the Table have synergies, overlaps and cross-effects, which must be understood and incorporated within an effective reduction strategy. For example, the effectiveness of measures to reduce automobile commuter trips could be reduced if additional traffic were attracted back onto the roads by a reduction in congestion levels from efforts to improve traffic flow. Alternatively, strategies to reduce car use could be enhanced if they were combined with efforts to provide convenient alternatives, and with supportive infrastructure investments and land use planning.

Transportation is a complex system of infrastructure, vehicles, fuels, service providers and consumers. A successful greenhouse gas reduction strategy will require actions throughout the system, and the coordination of interactions between system components. The national climate change process described in this article is an illustration of how the government can provide a supportive framework through which the necessary partnerships and coordinated actions can be developed.

Figure 7
Summary of measures identified by the Transportation Climate Change Table: potential reductions in 2010 (in millions of tonnes of CO_2 equivalent)

	Most promising	Promising	Total
Passenger	3.7	10.1	13.8
Road infrastructure	5.0	1.5	6.5
Road vehicles & fuels	—	8.9	8.9
Freight	2.0	7.0	9.0
Off-road	—	4.3	4.3
TOTAL	10.7	31.8	42.5
Reductions required if Canada's national Kyoto target (-6% from 1990 levels) were to be achieved in the transport sector			*54*

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Sustainable mobility: perspectives from the transport sector in East and Southern Africa

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Summary
A number of initiatives that could bring about improvements aimed at achieving sustainable mobility in East and Southern Africa have been studied. Energy efficiency could clearly be improved, and greenhouse gas emissions reduced, in these countries. Funding the measures needed remains a problem in view of the region's lack of financial resources.

Résumé
L'article passe en revue plusieurs initiatives visant à favoriser des pratiques de mobilité durables en Afrique orientale et australe. S'il est indéniable que l'on peut améliorer le rendement énergétique et réduire les émissions de gaz à effet de serre dans ces pays, financer les mesures nécessaires reste un problème à cause du manque de ressources financières de la région.

Resumen
Este estudio examina varias iniciativas que podrían contribuir a lograr un transporte sostenible en el Este y el Sur de África, donde es posible aumentar la eficiencia energética y reducir la emisión de gases de efecto invernadero. La financiación de las medidas necesarias sigue siendo problemática, dada la escasez de recursos de la región.

The importance of the transport sector with respect to development cannot be overemphasized. In Africa, as in other parts of the world, transport is an engine of economic growth. It moves goods and passengers to national, regional and international markets. There is a trend for countries to form economic entities such as the Southern African Development Community (SADC), the East African Community (EAC) and the Economic Commission of West African States (ECOWAS). Transport can also be considered a means of regional integration, linking people and regional markets.

Transport is one of the fastest growing economic sectors, in terms of energy and infrastructure demand and proliferation of vehicle fleets. While transport's energy share in East and Southern Africa (ESA) varies according to country (**Figure 1**), it averages 12% of national final energy consumption.

Petroleum products are the dominant fuels in all ESA countries. In seven countries, these products provide all the energy used in the transport sector, and in the rest they provide over 80% (**Figure 2**). Except in Angola and South Africa, all petroleum products are imported, depleting scarce foreign currency. Electricity and coal are used to a limited extent, particularly in the case of rail transport (**Figure 3**).

Typically, road and rail are the major transport sub-sectors, with road transport alone representing about 72% of total energy consumption (**Figure 4**). Construction of road and rail infrastructure also contributes significantly to the debt burden. External loan financing is provided by multilateral lending institutions such as the International Bank for Reconstruction and Development (IBRD) and the African Development Bank.

Apart from requiring infrastructure investment and fuel imports, the transport sector is far from efficient in delivering goods and services. If this sector is to be a driving force for much needed economic growth in the ESA countries, it must meet the needs of all transport consumers in a sustainable fashion.

Sustainable mobility in ESA countries therefore means ensuring efficient movement of passengers and goods (and having efficient energy systems and adequate infrastructure), without depleting already scarce foreign currency or increasing international debt.

Sustainable transport mobility in this context would involve the following:

Providing adequate road and rail networks
Most roads are unpaved or poorly maintained. Maintenance of the existing infrastructure has been neglected, obviously due to lack of financial resources as well as to resource mismanagement. Revenue generated in the transport sector is not directed at maintaining infrastructure, but is often channelled to other sectors with immediate financial needs.

Railway lines exist only along specific confined routes, with little flexibility for delivery of goods and passengers. The region's railway systems are poorly managed and tend to operate below capacity. In general, they operate with run-down equipment, are unsafe for both freight and passenger delivery, have long turn-around times, and operate at a loss owing to public mismanagement.

Inadequate telecommunication facilities in ESA countries (there are generally fewer than two telephones per 100 people) imply greater reliance on motorized transport systems for communication, particularly in urban areas. Frequent travel results in more demand for transport energy, more local and global emissions, and more fatalities.

Achieving high energy efficiency and low energy intensity in vehicles
African countries have low per capita incomes, and vehicles are generally over ten years old. These vehicles, which have high energy intensity due to poor maintenance and outdated design, continue to increase in number, as the ESA countries encourage the import of second-hand vehicles. The age of cars and light-duty vehicles (LDVs), which have the dominant modal shares in the region, contribute significantly to high energy consumption, impacting on both GHG and local air emissions.

The region has limited and unreliable mass transport facilities, so that use of private vehicles is predominant. The large fleet of private cars and LDVs contribute more GHG emissions per passenger-kilometre or tonne-kilometre than would mass transit used for the same purposes.

Substituting current petroleum products with low-emission fuels/energy sources (e.g. ethanol, CNG and hydroelectricity)
Fuel substitutes such as ethanol, compressed natural gas (CNG) and hydroelectricity can be made available in the region. Their use would reduce imports of imported petroleum products and limit environmental problems like air pollution and GHG emissions.

Ensuring practical application of the proposed measures
The right policies and necessary skills, institutional strengthening, legal frameworks and, more important, financial resources are also of paramount importance in ensuring successful application of proposed transport measures.

The East and Southern African countries are

Table 1
Sustainable mobility measures in East and Southern Africa

Infrastructure	Energy efficiency	Fuel substitution	Regulatory/policy measures
◆ Mass transit systems (e.g. rail for road freight)	◆ Enhanced vehicle maintenance	◆ Compressed natural gas (CNG) for gasoline/diesel	◆ Vehicle inspections (maintenance and pollution)
◆ Non-motorized transport	◆ Fuel use efficiency	◆ Enhanced ethanol blending	◆ Fuel pricing
◆ Road paving and maintenance		◆ Hydroelectricity for diesel	
◆ Enhanced communications measures			
◆ Integrated transport and urban planning			
◆ Pipeline for petroleum transported by rail or road			

currently debt-ridden. Most of them are no longer sufficiently credit-worthy to satisfy requirements for sustainable transport mobility. Perpetuating the conventional transport system, however, means continuing high bills for petroleum products (and associated debt), traffic congestion, accidents, and noise and air pollution. The ESA countries' contribution to GHG emissions would also continue to increase unabated. Some countries are already failing to meet their transport fuel demand through lack of foreign currency. Zimbabwe is a case in point.

The potential to address these transport problems seems to depend on integrating transport plans with the current global effort to reduce greenhouse gases, since policies with a wider variety of social, economic and environmental objectives will also result in GHG reductions. GHG reduction strategies are likely to be more acceptable in ESA countries, and more successful, if integrated into broader transport, urban development and environmental policy strategies.

The energy and climate change link

Estimating a baseline for transport sector energy and GHG emissions from per capita transport energy and per capita GDP can be useful if reliable future GDP and population growth rates are known.[2] Figure 1 shows such a result, based on an analysis of transport energy in ten Southern African Development Community (SADC) countries. The relationship of per capita transport energy to per capita GDP holds in cases where there is no serious economic and political turmoil (Figure 2).

The equivalent CO_2 baseline for SADC countries to 2050, based on this type of energy-emission nexus, is shown in Figure 3. Transport sector emissions are estimated to reach about 250 Mt in 2050, up from 55 Mt in 1990. While this makes transport a significant emitter, the power sector is estimated to emit about twice this level of emissions in 2050.

Transport continues to be one of the fastest growing sectors, in response to rapid population growth and urbanization. It is also responsible for significant emissions of high global warming potential (GWP) gases such as N_2O and NO_x. This justifies addressing transport sector related problems in the context of the UN Framework Convention on Climate Change (UNFCCC). It is envisaged that as part of the global effort to limit GHG emissions, ESA countries can obtain technological and financial resources to improve transport sector efficiency.

Sustainable mobility measures

Many kinds of sustainable mobility measures can result in GHG reductions: they range from technological (e.g. fuel substitution) to regulatory/policy-orientated (e.g. imposition of duties) to behavioural (e.g. education on driving practices). Several such measures identified as applicable in the transport sector in ESA countries are listed in Table 1.

Transport infrastructure

Providing or improving mass transit systems to replace large fleets of old cars and LDVs, and providing access to transport services and mobility in many EAS countries

The Second Assessment Report of the International Panel on Climate Change (IPCC) estimates that primary energy use could be reduced by 30-70% through switching from car to bus or rail. Both transboundary corridor and metropolitan mass transit systems would improve access to transport services, mobility and air quality, as well as reducing GHG emissions. Intra-urban, inter-urban and regional corridor routes could be considered for both freight and mass passenger transport.

An examination of regional transport corridor options for shifting road freight (dry cargo) to rail between Zimbabwe and Beira in Mozambique provided insights into the mitigation capacity of such options.[3] Abatement of 15,000 tonnes of CO_2 equivalent per year (at US$ 8.6/tonne) was projected. The GHG reduction capacity increases if more regional corridors and expanded freight transport are considered.

A similar mass transit option considered in an in-country case study for Botswana revealed a potential for reducing 77,000 tonnes of CO_2 equivalent in 2005 and 161,000 tonnes in 2030 (at US$ 100 per tonne) through shifting 40% of cargo transported between the north and south of the country, which is currently the road freight share, to rail.[4]

Mass transit could be considered for urban areas, shifting passengers from minibuses to coach type buses. Analysis of this option for Uganda showed a potential reduction of 64,0000 tonnes of CO_2 equivalent per year (at US$ 2.65/tonne).[5]

Concerning mass transit systems, the benefits of reduced energy intensity increase with the load increase. In all these cases, the necessary policies

Table 2
Technical and economic potential of selected transport measures

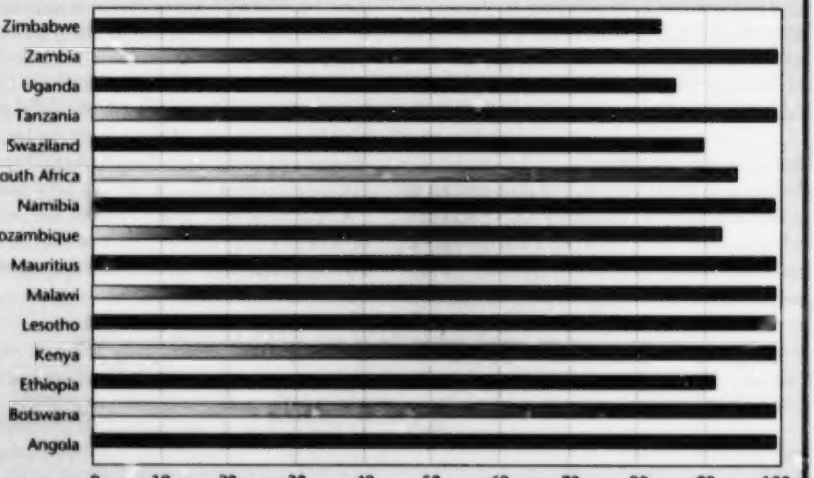
Measure	Location	Technical potential (cumulative GHG reduction potential, million tonnes of CO_2 equivalent)	Period	Economic potential (US$/tonne)
◆ Mass transit system – road freight – rail	Regional Corridor – Mutare-Beira	0.67	2005-2050	8.58
▲ Mass transit – road freight - rail	Botswana	2.31	1995-2030	-100
■ Mass transit – minibuses – coaches	Uganda	23.7[1]	1993-2030	2.65
▲ Non-motorized transport	Uganda	26.8[1]	1993-2030	6.10
▲ Road paving	Botswana	6[1]	1995-2015	-1251
◆ Pipeline	Pretoria – Gaborone	2.6	2005-2050	63.41
▲ Fuel efficiency – gasoline –diesel	Botswana	~1[1]	1995-2030	fiscal free
◆ Fuel substitution – CNG	1% of RSA cars and LDVs	5.4	2005-2050	1.37
○ Fuel substitution – ethanol	Zambia	3.3[1]	1995-2030	-97
◆ Fuel substitution – electric	Zimbabwe – Mozambique – Mutare-Beira	2.55	2005-2050	27.57
▲ Fuel substitution – electric	Botswana - N-S rail - cargo	1.81	2005-2030	343
▲ Regulatory – vehicle inspection	Botswana	~10.99	1995-2030	0.6 to 1.7

1. Estimated cumulative emission reductions from annual estimated or averaged potential GHG reductions.

Sources:
◆ Zhou et al., 1998
■ Magezi, 1998
○ CEEZ, 1999
▲ Zhou, 1999

Figure 1
National transport energy share in ESA countries (%)

Figure 2
Petroleum's transport energy share in ESA countries (%)



(with incentives and fiscal measures) need to be put in place to encourage consumers to shift to mass transit.

Non-motorized transport

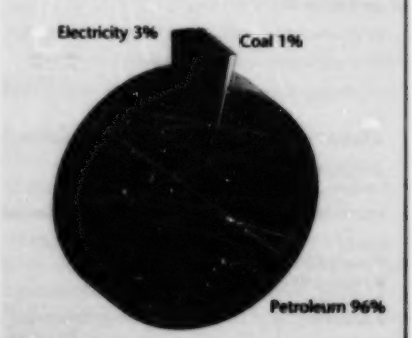
Non-motorized transport facilities, in the form of walking and bicycle paths, would result in affordable and emission-free transport. However, the obstacle in East and Southern Africa is lack of safe infrastructure. For example, cyclists are crowded off the road by motorists. This does not encourage more commuters to shift to cycling.

The bicycle, in particular, is a means of transporting farm produce in countries like Uganda. Designating cycle paths, and restricting certain city areas to non-motorists, would reduce urban congestion as well as energy consumption. The estimated GHG mitigation capacity of such an option, as analyzed for Uganda, is 725,000 tonnes of CO_2 equivalent (at US$ 5.1/tonne) in the case of 42 km of infrastructure.[5]

Unpaved and poorly maintained roads

Fuel consumption on unpaved roads (some very poorly maintained roads fall into this category) is about 1.5 times that on paved ones. Mobility is very limited on dirty roads and those with potholes, both of which are common in East and Southern Africa. Paving a 300 km section of road in Botswana was found to have the potential to reduce energy consumption, resulting in a GHG emission reduction of 300,000 tonnes of CO_2 equivalent annually (at a negative cost of US$ -120/tonne).[4] Other benefits include less need for imported spare parts, the demand for which increases when vehicles are used on bad roads.

Figure 3
Transport fuels in the ESA region



Pipelines to replace future demand for rail and road transport

Another infrastructure measure is the use of pipelines to move petroleum products from ports to the interior. The costs of maintaining roads and rail, and of fuel for freight vehicles, could therefore be reduced. To limit dependency on imported oil products, pipeline compressors could run on electricity in those countries with local hydropower resources.

A number of countries already have or plan to build such pipelines, but the potential exists for even more to be added. When consideration was given to constructing a pipeline from Pretoria, South Africa, to Gaborone, Botswana, the potential GHG reduction was found to be 57 000 tonnes of CO_2 equivalent annually (at a cost of US$ 63 per tonne).[3]

Energy efficiency measures

Increasing the share of fuel efficient vehicles

Increasing the share of diesel at the expense of petrol (gasoline) vehicles in Botswana was found to have the potential to reduce energy consumption equivalent to 15,237 tonnes of CO_2 emissions in 2005 and 41,000 tonnes in 2030 fiscally free. The measure operates on the premise that diesel vehicles have better fuel economy than those burning gasoline. Inducing the shift has been possible through increasing the tax on gasoline more than that on diesel. However, diesel would increase air pollution, and use of catalytic converters may also increase N_2O emissions.

Fuel substitution measures

Substituting CNG for petrol/diesel in vehicles

A typical example of use of CNG to substitute for liquid fuels, with some added benefits, is found in South Africa, where 22% of the liquid fuel consumed is produced from coal at a plant operated by the South African petroleum company SASOL. SASOL saves South Africa billions of Rand a year in foreign currency, limiting the economic impacts of oil shocks. The technology for converting natural gas to liquid fuels already exists in South Africa. Converting 1% of cars and LDVs from gasoline to CNG was found to have the potential to reduce 120,000 tonnes of CO_2 equivalent annually between 2005 and 2050 (at US$ 1.37/tonne).[3]

There have been significant natural gas discoveries in East and Southern Africa. Coal bed methane can also be used as fuel. Using these fuels would achieve sustainability of fuel supply, despite calculated constraints imposed by the oil-producing countries.

Enhancing ethanol blending

Another important fuel substitution option would be to introduce or increase ethanol blending with petrol where feedstock such as sugar cane can be produced and sustained. Some established plantations and infrastructure for ethanol production already exist in ESA countries. Zimbabwe, Malawi and Kenya have already used ethanol blend. There is momentum in Zambia and Uganda to follow suit. In a case study on introducing a 20% blend for gasoline vehicles in Zambia, the potential GHG emission reduction was estimated to be 72,000 of CO_2 equivalent in 2010 and 120,000 tonnes in 2030 (at a negative cost of US$ -97/tonne).[6]

Ethanol is sometimes not cost-effective as a transport fuel when petrol is cheap on the international market. However, repeated oil shocks suggest that the region should maintain a level of self-sufficiency.

Electrifying rail systems using hydropower

Electrification of rail systems is seen as another measure to achieve sustainable transport mobility. Electricity is produced in this region – unlike petroleum products, which must be imported. Experience in the region is that electric trains can pull greater loads than those running on diesel, providing benefits in terms of economies of scale. The GHG reduction potential could be significant where the source of the electricity is hydropower.

For Botswana, it was estimated that the same freight shift from road to rail, and electrification of the rail system using imported hydropower, would yield an additional GHG reduction of 57 000 tonnes of CO_2 equivalent in 2030, but at a high cost of US$ 300/tonne. The option is more cost-effective if loads are large, suggesting that it could be considered a long-term measure when regional loads have increased. This measure would be more practical for those countries with abundant hydropower.

Regulatory measures

Vehicle inspections

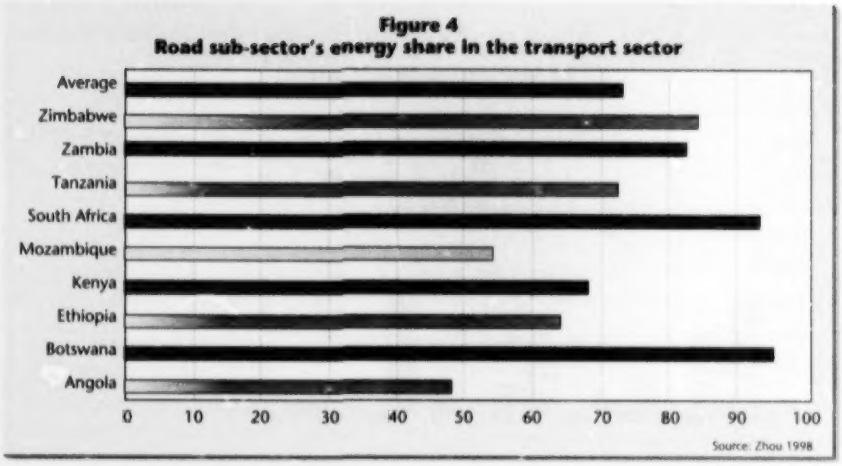
Introducing inspection for both road-worthiness and emission levels would encourage motorists to service their vehicles regularly and thus maintain high fuel efficiency. Garage owners estimate that a 10% improvement in efficiency is possible. The potential GHG reduction estimated for vehicles in Botswana alone was found to be up to 500,000 tonnes of CO_2 equivalent in 2030 (at less than US$ 1/tonne reduced).

Technical and economic potential of these measures

Table 2 summarizes the technical and economic potential of selected transport measures that could be implemented in the ESA region.

The technical potential of the measures considered above could translate into an average annual GHG reduction of 2.5 million tonnes of CO_2 equivalent, with over 75% implementable (at less than US$ 10/tonne of CO_2 equivalent reduced). When translated into petroleum fuels and into money terms, as much as US$ 500 million could be saved annually in a region strapped for foreign currency. More could be realized through increasing the scope and number of transport measures. Reduced pollution would also contribute significantly to the benefits.

Figure 4
Road sub-sector's energy share in the transport sector



Financing

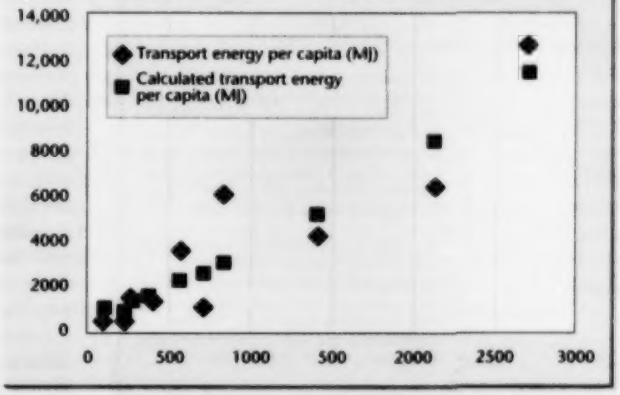
Serious consideration needs to be given to how such transport measures could be implemented, in view of the lack of financial resources in these countries. The UNFCCC foresees a financial mechanism providing grant and concessional funds to recipient countries for projects and activities aimed at protecting the global environment, through the Global Environment Facility (GEF).

The introduction of the GEF's Operational Programme 11 for transport measures is a welcome development that could address a number of transport needs in developing countries. What is most critical about GHG emission reduction measures aimed at the transport sector is estimating with a reasonable degree of accuracy the energy savings to be achieved through various actions. It is difficult to quantify the global benefits resulting from many measures, although it is understood that GHG emission reductions will be achieved.

The situation in developing countries such as those in East and Southern Africa is aggravated by poor transport data and lack of resources for monitoring such data. GEF OP 11 could be used to develop appropriate data for analyzing transport activities, as well as to stimulate the demand for such measures through demonstration projects. A lot can be learned, and management skills developed, through such GEF activities. There should be more emphasis in GEF financing on measures involving intricate data analysis with respect to achieved energy savings. The majority of measures in the infrastructure, energy efficiency and regulatory categories would be best addressed by this source of financing.

Furthermore, the Kyoto Protocol foresees flexible mechanisms such as the Clean Development Mechanism (CDM) and Joint Implementation (JI). Since these mechanisms require verifiable emission reductions, it would best to target measures for which GHG emission reductions could easily be calculated, as in the case of fuel substitution and infrastructure (e.g. pipeline) options. Projects could also involve corridor transport studies, where traffic monitoring is possible and modal shares can be estimated, allowing projections of demand for transport services and of GHG emissions avoided when improvements are made to corridor systems.

Figure 5
Transport energy: GDP dependent scenario

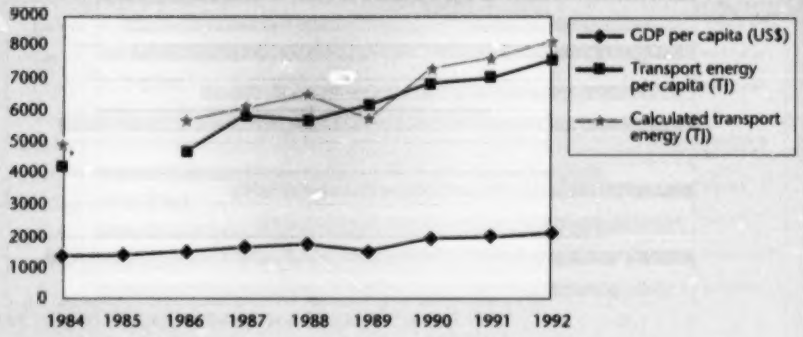


The developmental approach,[7] whereby transport project activities are implemented as part of an integrated transport planning process, will yield potential GHG emission savings but probably not be good enough as CDM and JI projects.

In light of these financing mechanisms, transport measures should be aimed at providing efficient transport services and reducing GHG emissions, while the international community is expected to shoulder the greater portion of the financial investment burden.

In addition to current financing from multilateral lending agencies such as the World Bank Group (IBRD,

Figure 6
Observed and calculated transport energy per capita vs. GDP per capita in Mauritius



the International Finance Corporation) and the African Development Bank, and from Official Development Assistance, a number of private sector financing options could be used to create transport infrastructure. These include "Build, Operate and Transfer" (BOT) and "Build, Operate, Own and Transfer" (BOOT) for new infrastructure, and "Finance, Rehabilitate, Operate and Maintain" (FROM) for rehabilitation of substandard transport infrastructure. Both local and international investors can inject their financial resources – local or foreign – and earn a return on their investment through the sale of services.

The various financing mechanisms need to be combined, maximizing the merits of each of them.

Institutional and legal framework

Transport measures that qualify as projects need to be marketed. Hence, institutions should be equipped to do business in this area. A legal framework is also required to ensure regulation of players, which will include the private sector, and to predetermine how the economy will benefit from such projects.

A concerted effort is required if ESA countries are to realize anticipated potential financial and technological benefits. This includes:

- establishment of information centres for financial sources, technologies, practices and management skills;
- a common agreed criteria for categorizing transport measures with respect to various financing mechanisms; and
- stressing direct involvement of regional expertise in the development of transport measures, to ensure the sustainability of technology absorption and the potential for upgrading such technologies in the future.

Deficiencies in both human resources and institutional capacity must be addressed, in order to make implementation of such transport measures possible.

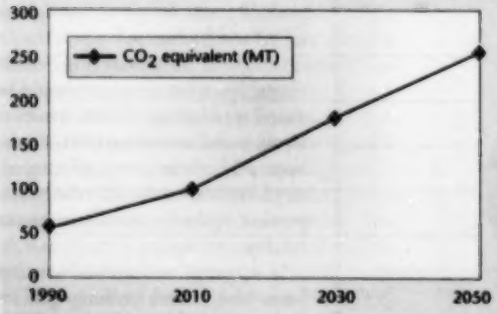
East and Southern African countries should therefore have deliberate policies to strengthen their institutions, create a conducive legal framework for introducing these measures, develop the necessary human capacity, and institute relevant research and development

Conclusions and recommendations

Conclusions

- Sustainable transport mobility can be realized in ESA countries by employing some simple and readily available technologies and practices already existing in the region. A good number of these measures are related to improvement of transport infrastructure and fuel substitution;
- Sustaining transport mobility would also require a measure of energy self-sufficiency to ensure security of supply in light of the behaviour of the international cartel constraining global supply. Use of regionally available energy fuels such as CNG, ethanol and hydro-based electricity could be developed;
- Since most of the measures presented in this paper can reduce greenhouse gas emissions, they can attract UNFCCC funding. These measures could also attract private sector financing when considered as service investments. Transport measures, in this regard, would limit debt accumulation and erosion of scarce foreign reserves/earnings;
- For all these measures to be implemented, domestic preparations for adopting and sustaining good practices are imperative.

Figure 7
Transport emissions in the SADC region, excluding DRC



In calculating CO_2 equivalent emissions, coal-liquid fuel conversion is ignored as we do not know how much of SASOL's synthetic fuels end up in transport. If we assume that SASOL's 22% share of total liquid fuels is the same in transport, CO_2 equivalent emissions in the SADC region could be higher by about 25-30%.

The share of gas conversion to liquid fuels has also been ignored. South Africa's contribution to total liquid fuels has been small (5%) and additional emissions have been correspondingly small. However, more natural gas will be used in synthetic fuels production in South Africa.

Recommendations

- ESA countries should be in a position to appraise various related transport measures as preparation for developing projects. GEF OP 11 funds could be applied for this purpose;
- Domestic institutions also need to match appraised projects with various financing sources;
- Conducive policies should be put in place to encourage both UNFCCC and private sector investments in transport;
- Possibilities on how to create employment through implementation of transport measures. An example is to involve communities in provision and maintenance of low level infrastructure like pedestrian and cyclist paths;
- It is also important to explore regional cooperation with respect to tapping, storing and distributing regional energy resources such as CNG, ethanol and hydropower.

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Enhancing the mobility of all road users: case study of Delhi

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Strategies to achieve sustainable mobility involve promoting public transport, increasing the share of transport modes that do not consume fossil fuels, reducing trip length, and promoting clean fuel technology for motorized modes, including public transport. The majority of trips in large Indian cities are made by non-motorized or public transport. However, these cities have unacceptable air pollution levels and peak hour congestion, along with high fatalities in road traffic accidents. Furthermore, trip lengths tend to be short partly because a large number of people are forced to live close to their workplace in "unauthorized settlements".

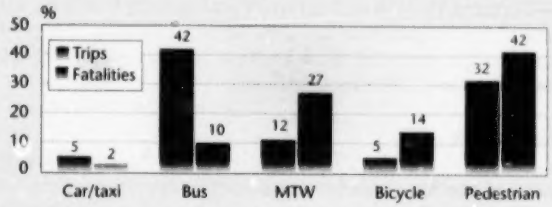
Such transport patterns cannot be described as sustainable. They suggest that dependence on environment-friendly modes of travel exists in these cities since a large section of the population does not have any other option. In fact, the trend over the last 20 years shows that with increases in real incomes use of motorized private transport (cars and two-wheelers) also increases.

Even with subsidies, use of public transport remains cost-prohibitive for much of Delhi's population. Assuming a minimum of four trips using public transportation per household per day, at Rs. 4 (US$ = Rs. 40) per trip the household would need to spend a minimum of Rs. 160 per month per person for 20 working days. In the case of low-income people living on the outskirts of the city, the cost per trip may be Rs. 8-10, depending on the number of transfers. On average, a household cannot spend more than 10% of its disposable income on transportation. This implies that monthly household income needs to be at least Rs. 3200 for the public transport system to be used at minimum rates. A 1994 survey[1] found that the monthly income of approximately 28% of households in Delhi is under Rs. 2000. In outer areas, the presence of non-motorized vehicles (NMVs) and pedestrians on some important inter-city highways with comparatively long trip length[2] demonstrates that many people use these modes not out of choice, but rather because they lack other options.

Since commuting to work is necessary for survival, people continue to use these modes despite a hostile physical environment, high risk, and inconvenience. Pedestrians and bicyclists are the most vulnerable group with respect to traffic fatalities. **Figure 1** shows the proportion of trips made by different modes in Delhi and the distribution of fatalities. The risks are greatest for bicyclists and lowest for bus users, although there are no estimates concerning fatalities associated with access to cars or buses. Bus commuters are often killed or injured when entering or leaving the bus, or when they fall off a moving bus (there are no doors on Delhi's public buses). If deaths associated with access to buses were included in the statistics, the number of bus commuters killed would be higher than is shown in Figure 1.

The risks associated with bus travel must deter private vehicle owners from using public transport. At present in Delhi, 62% of all motorized trips are made by bus. This share is likely to decrease as incomes increase. If it were maintained at present levels, the safety of commuters as bus users, bicyclists and pedestrians would need to be improved.

Figure 1
Trips and road accident fatalities for different road users, 1994



MTW = motorized two-wheeler

Source: D. Mohan and G. Tiwari, 1997

Priorities for improving transport infrastructure

Infrastructure policies do not adequately recognize the needs of public transport and NMVs. Investments in transport improvement plans continue to focus on projects that benefit car users at the cost of environment-friendly modes.

In 1997, the Government of India prepared a *White Paper* on pollution in Delhi.[3] Subsequently an Environmental Pollution Control Authority (EPCA) was set up for the city. EPCA's policy recommendations have been driven by environmental concerns aiming to achieve better speeds for motorized vehicles and less polluting fuels. These include the following:

- construction of expressways and grade-separated intersections;
- introduction of one-way streets, and of synchronized signals and area traffic control systems;
- construction of a metro rail transport system;
- phasing out of older buses and increasing the number of buses; and
- running the entire bus fleet on compressed natural gas (CNG).

Experiences from several cities suggest that construction of more high-capacity roads could have the unintended effect of reducing public transport and bicycle use, without increasing vehicle speeds or reducing congestion. Reductions in bus and bicycle use would result in higher pollution levels and possible increases in traffic congestion. No detailed studies have been carried out in order to understand the effect of these changes on road user behaviour in cities in low-income countries. It is possible that construction of high-capacity roads in these countries, at the expense of facilities for public transport and non-motorized traffic, may make things worse for everyone.

Socio-economic burden on the urban poor

The urban poor comprise almost 50-60% of the population in the cities of t'. South. In a recent survey in Delhi's slums, the residents noted that commuting to work is the most dangerous aspect of their work. Low-income households also spend a larger share of their income on transport, thus affecting other needs such as food, shelter and health. They are more vulnerable to events such as traffic accidents since they have no savings or any other social network. For this group, the economic and emotional costs of a traffic accident is enormous; there have been instances of families being forced to sell their meager assets, give up their temporary jobs, and take out loans that require a lifetime to repay.

Avoided costs due to investments in bicycle/NMV friendly infrastructure

Providing a separate bicycle/NMV track would make more space available for motorized modes, as well as making bicycling less hazardous. Our studies in Delhi show that on urban arterials the kerbside lane (3.5 metres) is used primarily by bicycles and other NMVs. Buses, which are unable to use this lane, are therefore forced to stop in the middle lane at bus stops. Motorized traffic does not use the kerbside lane even when bicycle/NMV densities are low. A segregated bicycle lane requires only 2.5 metres. Since most of Delhi's major arterials and those of many other Indian cities have a service road, the existing road is wide enough to accommodate a bicycle track without the need for additional right of way.

The 1998 Bicycle Master Plan for Delhi shows how existing roads could be redesigned in conformity with the given right of way to provide an exclusive lane for NMT modes (bicycles and three-wheeled rickshaws). **Figures 2 and 3** show designs for arterial roads with integrated NMV lanes, along with dedicated lanes for buses, pedestrian paths and service roads. These designs benefit all road users.

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Increased capacity
If a separate lane is constructed for bicycles, the kerbside lane becomes available to motorized traffic. This relatively small investment in bicycle lanes can increase the road space for motorized traffic by 50% on three-lane roads. Motorized vehicles benefit from improved road capacity and higher speeds. Capacity estimates for a typical arterial road in Delhi[4] show improvements of 19-23%. If the corridor's full capacity is utilized, with provision of a high-capacity bus lane in the kerbside lane, capacity improvements of 56-73% are possible (from a present carrying capacity of 23,000 passengers/hour to 45,000 passengers/hour).

Improved speeds
Buses and two-wheelers benefit from higher average speeds because the kerbside lane becomes available to them without interference from slow vehicles. On a typical arterial corridor in Delhi,[5] overall time costs are estimated to be reduced by 48% due to a 50% improvement in bus speeds (from the present 15 km/hour to 30 km/hour) and a 30% improvement in the speeds of cars and two-wheelers.

Reduced congestion
Delhi and other Indian cities have invested in grade-separated junctions and fly-overs as one of their major congestion relief measures, at an average cost of Rs. 100-300 million for each intersection. However, detailed simulation of a major intersection in Delhi shows that replanning the junction to include separate NMV lanes and a bus priority lane could result in an 80% improvement over the present level of delays. The cost of this measure is 25 times less than that of the proposed grade-separated junction.[6]

Increased safety
By creating segregated bicycle lanes and redesigning intersections, safety benefits estimated for a typical arterial in Delhi show a 46% reduction in accident costs through reducing accident injuries by 40% and fatalities by 50%.

Reduced pollution and energy consumption
Energy consumption and pollution are reduced since motorized vehicles drive more smoothly and faster. Estimations for the Delhi corridor show a 28% reduction in fuel consumption and a 29% reduction in health externalities related to air pollution.[7]

Induced bicycle trips
There are approximately 1 million households in the middle- to high-income category. If the average number of trips per household is two per day, at least 10% of these trips, especially by schoolchildren and young adults, could be new bicycle trips for recreation and school journeys. This group would benefit from expanding their opportunities to participate in different activities. It is difficult to express this benefit in money terms, however.

Vulnerable road users: the "critical element" in the city transport fabric

Urban transport systems in cities in developing countries can become sustainable, providing mobility with minimal adverse environmental effects, only if there is safe and affordable transport for all sections of the population. Nearly 50% of these cities' population needs to live near their place of employment. They also need inexpensive modes of travel in order to work to survive. If the planned transport system does not meet their travel needs, they are forced to live in sub-optimal conditions. They continue to live in places that were not planned for them. Consequently, land use and transport plans are violated and all transport modes operate under sub-optimal conditions.

The experience of the past decades of long-term integrated land use transport planning suggests that the existence of the informal sector and its travel needs must be recognized in preparing effective plans. This should encourage mixed land use patterns, and transport infrastructure especially designed for bicycles and other non-motorized modes.

Figure 2
Design of NMV lane and bus lane on urban arterial

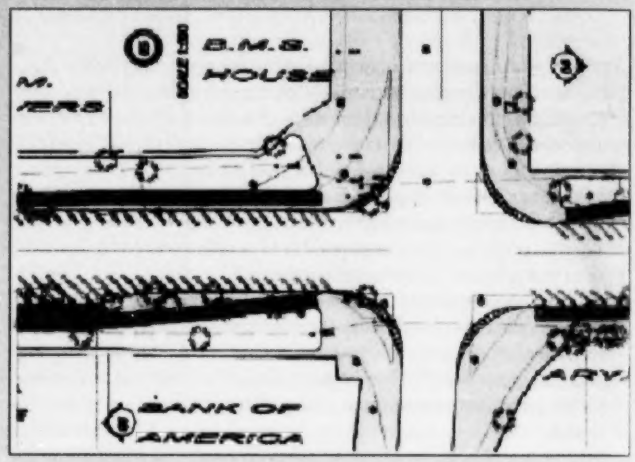
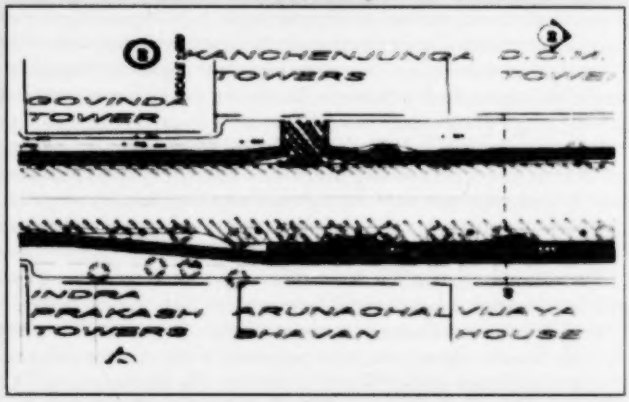


Figure 3
Design of urban arterial at midblock NMV lane, bus lane and bus stop



Notes

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Urban transportation in Latin America and the Caribbean: the example of Cuenca, Ecuador

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Summary

Providing urban transportation services that are financially, socially and environmentally sustainable is critical in Latin America and the Caribbean, where 75% of the population lives in urban areas. An efficient, cost-effective public transportation system, combined with effective land-use management, has been developed in Curitiba, Brazil. The Inter-American Development Bank supports efforts to adapt Curitiba's integrated approach to other medium and large cities in the region. In Cuenca, Ecuador, technical assistance has stimulated a multitude of changes in municipal transportation services.

Résumé

En Amérique latine et dans les Caraïbes, où 75 % de la population vivent en zone urbaine, il est urgent de mettre en place des services de transports urbains économiquement, socialement et écologiquement viables. Un réseau de transport efficace et rentable, associé à une gestion efficace de l'utilisation des sols, a été mis au point dans la ville brésilienne de Curitiba. La Banque interaméricaine de développement soutient les efforts d'adaptation de cette démarche intégrée à d'autres villes de la région, moyennes et grandes. A Cuenca (Equateur), par exemple, son assistance technique s'est traduite par de nombreuses modifications dans les services municipaux de transport en commun.

Resumen

Proporcionar un transporte urbano sostenible –tanto en términos financieros y sociales como medioambientales- resulta crucial para América Latina y el Caribe, donde el 75% de la población vive en zonas urbanas. En Curitibá, Brasil, se ha desarrollado un sistema de transporte público eficaz y económico, junto con una gestión adecuada del territorio. El BID apoya los esfuerzos orientados a adaptar este enfoque a otras ciudades de la región. En Cuenca, Ecuador, la ayuda técnica transforma el transporte municipal.

Transportation is critical to the vitality of a city. It can be an effective tool for catalyzing commerce and sustainable economic growth; promoting important cultural sites and fostering civic pride and identity; and integrating the poor and dispossessed into the urban community by offering a means of accessing jobs and education.

Unfortunately, few cities have successfully realized the potential that transportation can provide. Instead, they are increasingly grappling with problems associated with poor transportation services. These include skyrocketing investment and maintenance costs for transportation infrastructure, escalating air pollution, growing (and in many cases crippling) traffic congestion, rising levels of oil dependence, and diminishing access of the poor to transport services.

In the countries of Latin American and Caribbean (LAC), the challenge of designing sustainable urban transportation structure and services is particularly important. Over 75% of the population lives in urban areas. As incomes have risen in these countries, ownership of private motor vehicles has also grown sharply. It will continue to grow in the future, often at rates much higher than in industrialized countries.

With more vehicles on the road, air pollution problems are growing markedly, not only in the region's largest cities but in medium-sized secondary cities as well. Transportation, especially in urban areas, is also the largest source of fossil fuel based CO_2 emissions, which are a major contributor to climate change. Increasing traffic congestion, aggravated by the increase in the number of vehicles on the road, exacerbates these problems as more fuel is consumed and more emissions are produced in slow stop-and-go traffic.

The physical layout of urban areas in LAC has historically been characterized by dense development in which residences and businesses are mixed together. This is also beginning to change. With a growing number of wealthier urban residents and businesses able to move independently of public transportation systems by using private vehicles, urban sprawl has taken hold as part of the search for affordable and liveable environs. Political pressure is therefore increasing to expand the road infrastructure for these sprawled cities, resulting in a redirection of infrastructure priorities away from public transportation and pedestrian-friendly infrastructure. The inevitable result has been a sharp increase in the costs of building and maintaining urban transportation infrastructure, with the urban poor losing access to affordable transportation services.

Curitiba, Brazil: a model with little replication to date

Fortunately, within LAC there is a city that has become famous for taking a different approach to urban transport development – Curitiba, Brazil. The integrated approach taken by Curitiba was featured in *Industry and Environment* in June 1993. Leaders from LAC's large and medium-sized cities are increasingly studying this city, which is physically close and shares a common culture, to understand its characteristics and potentially adapt them to their own urban environments.

A key principle used in designing Curitiba's transportation system has been to integrate its design and operation with overall urban development goals, rather than isolating the transportation system's planning and implementation. The result has been an efficient, bus-based public transportation system built around five major arterial routes, on which the land use of the city is structured. Dense development is constrained to be within close proximity to the major bus corridors, with sparser development only permitted further away. As the city has grown, the most heavily travelled routes have been designated bus-only roads, and new bi-articulated buses (essentially three buses attached to each other with accordian-shaped connections) have been developed and introduced to handle larger passenger loads.

To facilitate ease and speed in using the system, it is "integrated" so that a fare (unsubsidized and reflecting actual costs of operating the buses) is paid once upon entering the system. Transfers to connecting buses occur at designated stops

through attractive "boarding tubes" at the same level as the buses (in a similar manner as when entering a subway train from a boarding platform). In essence, the city has evolved the efficiency of a subway at a fraction of the cost. With land use regulated, so that residences and businesses are within close proximity to the public transportation system, well over half the trips taken in the city are by bus, even though per capita car ownership levels in the city are among the highest in the country.

Old type of bus still used in Cuenca

Providing an integrated urban transportation planning strategy has been the city's planning agency, IPPUC, and its urbanization oversight agency, URBS. Private bus companies, which provide the actual bus services, receive "exclusive permissions" for specific routes subject to regulations established by IPPUC and URBS.

The result has been a transportation system that accomplishes a variety of urban development goals. With the same fare throughout the system, the poor, who live in the outskirts of the city, maintain access to affordable mobility. With high usage of buses rather than individual cars, which many residents now own, air quality problems are reduced. Well run, privately owned and operated bus companies are provided exclusive permissions to specific routes, within a structure in which they can flourish as businesses. Yet monitoring by URBS ensures that public health and safety are maintained. The result is a pleasant, liveable urban environment, reinforced with pedestrian zones, wide sidewalks and such innovative features for recreation and relaxation as a 24-hour street, botanical gardens and an opera house.

Urban transportation challenges for LAC and the IDB

For a regional multilateral development bank such as the Inter-American Development Bank (IDB), addressing the transportation service needs of urban environments in a manner that is financially, institutionally and environmentally sustainable is critical to urban development. Moreover, changes occurring in LAC have the potential to fortify efforts to define and implement effective urban transportation systems.

Democratization reforms have advanced progress in decentralizing governance from the national to the local levels. As a result, municipalities and cities are increasingly being provided the tools to define their own solutions and, through local elections, to have citizens convey to their municipal leaders whether the actions taken meet their needs. The LAC region also continues its commitment to privatize many previous government services while developing public regulatory institutions to ensure productivity and fairness, and to protect public health and safety. Hence, a body of experience is accumulating on how to regulate successfully.

The maturation of these institutional reforms, combined with rapidly deteriorating urban conditions and the experience provided by Curitiba, is resulting in greater interest and political pressure to foster other "Curitibas" in the LAC region. Yet the integrated approach taken remains unique, with other urban regions frequently concluding that only Curitiba had the leadership and capability to forge this innovative approach. Furthermore, cities in the region face more complex transportation issues than Curitiba did when it initiated its integrated strategy, including the increased affordability of private cars, their competition with public transportation systems, and the rapidly deteriorating air pollution conditions produced by urban transportation.

For municipalities and cities in LAC, the following paradox has emerged: conditions have never been more optimal for tackling the challenge of sustainable transportation in a long- term and sustainable manner, but the lack of examples of cities and municipalities to follow Curitiba has itself become a deterrent.

Institutions such as the IDB can play an important role in addressing this problem. The Inter-American Development Bank is a major source of financing for the LAC region, with a presence in all of the region's key development sectors and a broad range of financing and non-financial tools. It is also recognized as an institution that understands the region and its problems well. With its ongoing presence in the region and institutional stability, the IDB is able to provide continuity over time in the pursuit of long-term goals. Moreover, its multilateral character enables it to provide a focal point for international cooperation to meet new development challenges.

With these attributes, the IDB has begun to take on the challenge of fostering new integrated urban transportation models. A small programme in IDB's central Sustainable Development Department, the Sustainable Markets for Sustainable Energy (SMSE) Programme, has been working with the IDB's operational departments and interested national and sub-national governments to provide the necessary technical, financial and institutional resources. One of the most advanced of these activities, in Cuenca, Ecuador, will be described in some detail below. Nevertheless, interest in developing an integrated and sustainable urban transportation system is found throughout Latin America and the Caribbean, from the northern borders of Mexico to the southern cities of Chile.

The emerging model of Cuenca, Ecuador

Cuenca is Ecuador's third largest city after Guayaquil and Quito. With a population of about 300,000, it has a historic central area dating back to the earliest days of Spanish colonization, with ties to the Incan city of Tomebamba. In 1999, Cuenca's historic center was designated a UNESCO cultural heritage site.

Traditionally, public transportation in Cuenca, as in many other LAC cities, was provided by private individual bus owners or *transportistas*. Concessions for routes to be served by bus operators, grouped into co-ops, had been awarded by the national government in Quito. Overlapping routes had precluded operators from producing a sufficient income to maintain or even upgrade their buses, and had encouraged them to compete vigorously with each on the road for passengers. As a result, the quality of public transportation service was poor, with detrimental impacts on air quality and traffic safety.

The IDB initiated its discussions with Cuenca's municipal government in 1997, as part of early preparatory work for a municipal development loan to Ecuador that was to include a pilot municipal transportation component. At that time the country's Constitution was being rewritten, with the decentralization of many government functions from national to local level expected to be one of many changes. The Mayor of Cuenca, Fernando Cordero Cueva, an architect by training, knew the experience of Curitiba well and saw in these early conversations the potential to bring substantial economic, social and cultural benefits to the city by implementing an integrated transportation system.

In the months following the initial conversations, economic and political conditions in Ecuador deteriorated substantially, causing the municipal development loan to be put on hold. The fortunes of the municipalities declined as the economy shrank and national government resources dwindled. However, the Mayor's interest in pursuing an integrated transportation strategy remained. A proposal for technical assistance from the municipal government of Cuenca was submitted to the IDB, with an initial focus on reforming the public transportation sector, the major transportation mode for most of its citizens.

The Mayor's vision incorporated the integrat-

ed philosophy developed by Curitiba, with which the municipal government of Cuenca was developing a cooperative agreement to share experiences. In a country with rising unemployment, Cordero saw in a restructured transportation system the potential to foster public transportation businesses of sufficient size and sophistication to provide quality services, gain access to credit to upgrade buses, and offer long-term jobs for employees. The Mayor also envisaged a strategy to provide long-term mobility services for the municipality's poor, and hence continuing access to jobs and education. And he identified a mechanism for addressing the air quality and safety issue that was being raised repeatedly by a group of mothers of school-age children in the municipality, who feared the children's health and safety were imperiled by the old and poorly maintained buses passing each other aggressively on major corridors as part of the competition for passengers. Finally, the Mayor viewed the restructured transportation system as an important tool to protect Cuenca's soon-to-be-designated UNESCO Cultural Heritage site and to foster tourism, a potential source of future income.

Internal trust funds from the Japanese Government (administered by the Inter-American Development Bank) were secured to provide the initial technical assistance request. While the funds were managed by the IDB, terms of reference and the selection of the winning bid for the technical assistance were reviewed with the municipal government of Cuenca. An international team of Japanese, American, Brazilian, Argentinean and Ecuadorean experts was assembled, with the task of diagnosing the characteristics and problems of the existing public transportation system and proposing solutions – both institutional and structural – appropriate to the existing political, institutional and economic systems in the municipality and the country.

A process of building support among the municipality's citizens, especially its *transportistas*, was also initiated. In 1998, a public meeting with representatives from the city of Quito was held to learn from experiences in that city, which had earlier developed a popular, clean, publicly owned trolley system. Quito had created a planning and regulatory unit to oversee municipal transportation, and to begin to develop an integrated system similar in philosophy to that of Curitiba. The offices of Cuenca's Mayor and Municipal Council sponsored several additional public meetings, often scheduled to coincide with visits from the IDB, to ensure all "stakeholders" that they would benefit, and to provide them with the opportunity to air their concerns. Stakeholders included the *transportistas*, the national police (which has historically been responsible for urban transportation enforcement and traffic control) and Cuenca's citizens.

Hindered in moving forward in restructuring Cuenca's transportation system by a national government preoccupied with economic and political difficulties that had slowed transference of

Type of bus to be introduced

governance responsibilities from the national to the local level, Mayor Cordero proposed an alternative. Cuenca would serve as a "pilot" for transferring municipal transportation responsibility from the national to the municipal level. In May 1999, coinciding with the launch of the IDB's technical assistance, an agreement was signed on behalf of the municipal government of Cuenca and the national Ministry of Government, formally establishing this transfer on a pilot basis. Several conditions for the transfer were defined, including creation by the municipal government of a new unit, responsible for planning, organization and regulation of urban transportation within Cuenca's jurisdiction (Unidad Municipal de Transito y Transporte or UMT), and establishment of a set of local ordinances approved by the Municipal Council to codify the assumption of responsibilities by the municipal government.

In the ambience of creativity fostered by this technical assistance and the commitment of the municipality's leadership, changes were seen very quickly, often outside the immediate focus on public transportation. For example, recognizing that illegally parked vehicles were a major barrier to the free flow of vehicles, including buses, the municipality awarded a concession to a private company for parking enforcement: illegally parked vehicles were "booted" and charged an administrative fee for removal of the boot. Within a few months, the results with respect to the free flow of traffic were visible, particularly along the narrow streets in the historic part of the city, which had previously been gridlocked. At the same time, to facilitate greater pedestrian access to Cuenca's streets (with clear benefits for local entrepreneurs) sidewalks in key parts of the city were widened.

As the technical assessment proceeded, the consultant team was asked to "preview" some of their recommendations in key areas to municipal leaders so that appropriate actions could be taken. In doing so, the municipal government sought to keep up the momentum and maintain support from key stakeholders. For example, previewing the results of air quality measurements that indicated significant air pollution along the most heavily travelled bus routes resulted in priority being assigned to removal of the oldest and most polluting vehicles from the bus fleet.

The UMT also began to take shape. Rodrigo Torres, who had played a key role in the Quito public transportation reform experience, joined the UMT as its director. One of its first activities was registration of all existing buses and enforcement of minimal standards, including stopping at designated bus stops and having safety equipment such as windshield wipers and headlights in working order. Revenues from the registration and enforcement process enabled the UMT to begin to hire additional staff, which included over a dozen architects, economists, engineers and administrative staff by December 2000.

The final report of the technical assessment team was provided to Cuenca in February 2000. Since the report's completion, the UMT has continued to move forward in redefining the city's public transportation system. The means of assigning routes has been restructured. Seventeen concessions that had been awarded to co-ops of individual *transportistas* with overlapping routes have been reduced to seven concessions to individual companies with no overlapping routes. The fares charged passengers have been restructured to be transparent and based on real costs. With clear indications of air pollution problems from the existing buses, which are an average 18 years old, plans are in place to replace 110 older buses by the end of 2001 and bring the average age of the bus fleet down to 10 years.

While the companies that will need to comply with these replacement requirements have little credit history, the new fare structure – in combination with good ridership information – has resulted in indications from a variety of bus manufacturers that they would be willing to provide credit directly to the companies on the basis of their projected income. Moreover, the UMT plans to start a voluntary programme of measuring tailpipe emissions for individual buses, as part of an educational strategy to gain support for replacing highly polluting buses.

Next steps

The progress being made in Cuenca has already attracted interest from other municipalities in the country, and outside it. Agreements on cooperation have been signed by the municipality of Cuenca with the smaller Ecuadorian municipalities of Loja, Manta, Azogues, Ambato and Machala and the larger cities of Quito and Guayaquil. The challenge now is to maintain the momentum, with the goal of fostering another example of an integrated approach to meeting future urban transportation needs in Latin America and the Caribbean. ◆

Ethanol as a solution to the pollution problem in the Metropolitan Area of Mexico City

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Air quality in the Metropolitan Area of Mexico City depends, among other things, on the volume and danger of the pollutants emitted, their chemical behaviour, and the meteorological dynamics determining their dispersion, transformation and removal in the atmosphere.

The volume of emissions is influenced, in turn, by various factors. The most important are: vehicle technology, industrial and service technologies and production volume, urban structure (area, density and diversity), the modal mix of transport, and total kilometers travelled.

The geoclimatic characteristics of the Metropolitan Area of Mexico City are responsible for the seriousness of its air pollution problems. Mexico City is approximately 2240 metres above sea level, and it is the country's most important urban and industrial area. The oxygen content of the air is about 23% less than at sea level, affecting vehicles' internal combustion process and contributing to industrial and service establishments being less efficient and generating more pollutants than if they were located elsewhere.

Analysis of air pollution

The transport sector is almost 100% dependent on two fossil fuels: gasoline (petrol) and diesel. All fuels (both renewable and fossil) that could conceivably replace them may therefore be defined as "alternative". Burning of any fossil fuel is closely related to the amount of pollutants in the atmosphere. Mexico City, together with surrounding urban areas, consumes over 44 million litres of fuel per day. This fuel powers more than 3.5 million vehicles, as well as supplying some 130,000 industrial and service establishments, two large thermoelectric plants and over 2 million homes.

Mobile sources consume more than 80% of this fuel and are responsible for generating about 78% of atmospheric pollutants. They produce approximately 77% of emissions of nitrogen oxides (NO_x) and 33% of those of hydrocarbons (HC), both of which are ozone precursors. These sources also account for 99% of carbon monoxide (CO) emissions. Industry and the two thermo-electric plants burn less than 20% of the fuel used daily in the Metropolitan Area and generates about 17% of NO_x and 3% of HC emissions. CO represented 87% of total pollutants emitted to the atmosphere in 1996, measured in tonnes/year, followed by HC and NO_x.

Traffic structure

The amount of polluting emissions depends on several factors, including the number of vehicles on the road, their average age, vehicle technology, and the presence of emission control systems.

Fuel quantity, type and quality also have a determining influence. To a considerable extent, the number of vehicles now on the road and their age reflect the economic conditions that have prevailed during the last four decades. These include the rapid economic growth of the 1960s, 1970s and early 1980s and the severe financial problems of the mid 1980s and mid 1990s.

It is striking that only some 39.5% of vehicles now on the road can be considered relatively new. The remainder are over ten years old. This fact alone goes a long way towards explaining the high pollution levels. Despite reduction efforts, pollution is still acute. Measures aimed at reducing it have achieved few satisfactory results. Incidents of pollution related health problems remain high.

Local government has promoted environmentally friendly fuels and efficient transport in an effort to reduce vehicle emissions. One fuel option is natural gas; another is sugar based ethanol, used both as an oxygenating additive and as pure bio-ethanol.

Transporting people or consumer goods presents a particular challenge with regard to making a commitment to achieve sustainable development. Transport causes or contributes to climate change, damages the ozone layer, and generates organic and inorganic toxic substances, air pollution and environmental damage, among its other effects. It is one of the few sectors in which trends are moving in the wrong direction if sustainability is to be attained.

Alternative fuels

There have been efforts over the last two decades to reduce harmful emissions through improving fuel quality and vehicle efficiency. The introduction of alternative fuels has occurred rapidly over the last three decades. Several alternative fuels exist. They have different characteristics in terms of environmental friendliness, availability, and so on. The number of alternatives that might be of interest in the future, and that are based on renewable sources of energy, is quite small. It is mainly bioalcohols that could be used.

The expanding use of alternative fuels produced from renewable resources, as in the case of ethanol, began in the United States and Brazil at the end of the 1970s. Ethanol use was developed in these two countries both as a strategy to reduce dependence on foreign oil and out of the conviction that the environment must be improved.

When a bio-based fuel, such as ethanol or biogas, is combusted, the CO_2 remains in a closed ecocycle: the amount of CO_2 released during combustion equals the amount plants absorb for growth. Total CO_2 does not increase, provided bio-based fuel is used at all stages of production and distribution. As bio-ethanol is derived from virtually inexhaustible energy sources, it is an excellent solution to the CO_2 problem. Mexico has access to a plentiful supply of ethanol. There is considerable potential for running vehicles on ethanol alone, or on ethanol blended gasolines.

Engine alcohols

Use of alcohols as vehicle fuels is not new. They were burned used the earliest years of motoring, and this practice has continued on and off throughout its history. Most often they have been seen as alternatives to conventional fuels in times of uncertainty, such as war or economic depression.

As vehicle fuels, alcohols have both advantages and disadvantages. Whether positive or negative characteristics predominate depends to some degree on the type of engine used. Generally, it may be said that alcohols often provide advantages if used in otto engines. In diesel engines there are physical obstacles that make alcohol use difficult.

Engine alcohols produced from biomass can be used as vehicle fuels in pure form and in blends with gasoline or diesel. Ethanol appears to be the best alternative among the engine alcohols. In contrast, methanol is highly toxic and corrosive and consequently makes very heavy demands at all stages of handling. At present, methanol can be produced at lower cost than ethanol. But as new, more efficient processes are developed for ethanol manufacturing, this cost advantage is eventually expected to be less great.

In the longer term, promising techniques and adequate potential for raw materials are available to permit ethanol use on a large scale, as well as use of biofuel to produce power and thermal energy. Any limits on how much might be used mainly concern on the ability to produce ethanol at competitive prices.

Techniques are already available for using ethanol or biogas as a fuel in either light or heavy vehicles. To obtain a technically and environmentally sound product, however, these vehicles would need to be optimized to realize the full environmental potential. This would require further development work on engines and catalysts.

The central area for engine development is optimization of ethanol engines for heavy vehicles that do not require addition of ignition improvers to the fuel. Various types of engine of this type could be based on systems involving sparking plugs, glowplugs, or the like.

Assessments

We asked the Mexican Institute of Petroleum to carry out an assessment of gasoline-ethanol mixtures in automotive vehicles. The study was based on emissions tests of vehicles representative of all those on the road in Mexico City. The sample was taken from the 1997 vehicle census of 3,057,570 vehicles, measuring kilometres/day, kilometres/year-vehicle and emission factors for gasoline with 5% MTBE and comparing with gasoline without MTBE and with 6% ethanol.

If this substitution took place for all the vehicles on the road in Mexico City, it would reduce air pollution annually by:

- 273,000 tonnes of CO, equivalent to a 21% decrease;

- 2900 tonnes of HC, equivalent to a 3% decrease;
- 50 tonnes of formaldehydes (HCHO), equivalent to a 12% decrease; and
- 13 tonnes of butadiene (C_4H_6), equivalent to a 2% decrease.

Use of ethanol would, on the other hand, increase vaporous emissions and emissions of NO_x, aldehydes (CH_3CHO) and benzene. Assessments must be continued in order to determine the possible health and environmental consequences of increases in aldehyde and evaporative emissions.

In addition to environmental and health advantages, the Ethanol Programme of Mexico's Federal District Government has certain aspects of social and economic relevance in our country that justify it in themselves. These concern, for examle, beginning production of alternative fuels and supporting agroindustry, which is of fundamental importance to the economy of 15 states and provides 2,350,000 jobs directly and indirectly. Not less important for the country's finances is the substitution of nationally produced sugar-based ethanol for imported oil and MTBE.

Strategies for the future

Changing the transport system towards sustainability requires various types of government input. However, in a market economy this is not merely a question of working out detailed plans for the future. It is also a matter of creating long-term conditions for market players. Different strategies for introducing biofuels are necessary, to indicate the desired direction and to stimulate proposals for various means of control that may be needed to meet environmental targets.

A change-over to a sustainable transport system involving the transition from fossil fuels to biofuels is a long-term process that needs to begin now in order to succeed. Pilot and demonstration plants for production of biofuels must be expanded, as well as fleets of vehicles that can run on these new fuels. Biofuels should be introduced within a broad and long-term programme including both ethanol blends in gasoline and targeted measures aimed at ethanol use in heavy vehicles.

The government will play a key role in bringing about greater use of biofuels. Its responsibilities should include an unambiguous adaptation of taxes and charges on fuels, so that fuel prices reflect health and environmental effects. As this involves substantial long-term investments by new players who will be involved in building up a new market for biofuels, the government needs to employ consistent and sustainable means of control.

Our citizens deserve both clean air and clean water. We are looking forward to concluding an agreement soon with PEMEX (Petróleos Mexicanos) to provide gasoline that does not contain harmful MTBE and begin gradual substitution of ethanol for this oxygenant.

A European NGO's view of transport and the environment

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Summary

Two key issues need to be addressed in moving towards sustainable transport: how to expand access, and how to make transport pay its environmental costs in accordance with the polluter pays principle. Switzerland has implemented policies that address both these issues. The environmental impacts of the fast-growing aviation industry are difficult for national authorities to address, particularly in view of the its global nature.

Résumé

Deux questions majeures doivent être abordées pour évoluer vers des moyens de transports durables : comment élargir l'accès aux moyens de transport et comment leur faire supporter leur coût environnemental en vertu du principe du "pollueur payeur" ? La Suisse a pris des mesures dans ce sens, mais les impacts sur l'environnement des transports aériens, actuellement en plein essor, sont un problème difficile pour les pouvoirs publics, notamment en raison de leur envergure mondiale par nature.

Resumen

El esfuerzo en pro de un transporte sostenible ha de tener en cuenta dos aspectos clave: cómo ampliar el acceso y cómo lograr la aplicación del principio de "quien contamina, paga". Suiza ha establecido normativas que atañen a ambos. El impacto ambiental de la dinámica industria aeronáutica plantea problemas de difícil solución para las autoridades nacionales, en particular por su índole mundial.

The main problems of transport and their causes are well known. For example, air pollution and CO_2 emissions from road transport are continuing to rise, despite great technological improvements, and noise is a huge problem affecting millions of citizens. Most of the problems – such as those associated with land use planning – have been public knowledge for years.

At the same time, the effects and consequences of environmental pollution from transport are increasingly being recognized. A study published in the first quarter of 2000 by the independent consultants INFRAS and IWW, for example, estimated the external costs of transport in Western Europe, excluding congestion, at Euro 530 billion per year (7.8% of the combined GDP of the 17 countries included) while the medical journal *The Lancet* reported in September 2000 that air pollution from road transport kills more people each year than road accidents.

The problems of aviation have been well publicized, at least since the Intergovernmental Panel on Climate Change (IPCC) published its *Special Report on Aviation and the Global Atmosphere* in 1999.

Still, far from enough is being done. Why? The crucial ingredient, political will, is missing. Lack of action stems from two fundamental but erroneous beliefs:

- First, growth of transport is believed to be strongly related to economic growth. Increasing transport volume and infrastructure growth are seen as indicating that the economy is doing well, and more transport is perceived as contributing to an improved economy. This is a powerful myth.
- Second, politicians believe taking measures to reduce transport's environmental problems will be very unpopular. The recent wave of fuel protests in Europe might be thought to support this argument. Yet these protests have been about unfair taxation and suddenly changing prices. While people may be reluctant initially to change their individual behaviour, a well informed public will support initiatives that move towards an environmentally sustainable transport future, as the Swiss example shows.

A carrot and stick approach is needed. The carrot is a series of good policies, like better land use so that operating a car is less sensible than walking, cycling or using public transport for the

majority of daily journeys. The stick is making transport pay its full costs – the principle of fair and efficient pricing which the European Union has accepted, but so far failed to implement.

Political will can be generated when decision-makers feel the warm glow of public support or are convinced their policies will improve well-being. Businesses interested in transport provision also have a role to play: they can make a lot of money in the long term if they move towards providing access in an economically efficient way. The rest of this article briefly describes a way to move towards sustainable transport.

Access is the key to urban transport problems

Providing access is the key to changing people's travel behaviour. If cities are set out according to typical New World style grid patterns, of course people will use cars, especially if there is a great distance between residential areas and places of work and/or shopping areas and in cases where there is little public transport to provide access to goods and services. In such a scenario, the car is seen as a necessary part of life and owning one soon becomes a "human right".

In many places, people who cannot afford cars look enviously at their neighbours who can. There is an element of pleasure and prestige in owning a vehicle, as advertisers are well aware, and "the road" has become a powerful symbol in most societies. Yet, more importantly, a car provides mobility to the user. In urban settings mobility is typically not as great as people believe, with congestion resulting in cyclists and even pedestrians often being more mobile than motorists.

If one "unpacks" the concept of mobility, it is clear that people usually do not seek mobility for its own sake: they want it in order to have access to goods, services, workplaces, schools, etc. Very often they do not like making the journey they are obliged to make. If people's daily reality is such that they feel they need a car, then transport policies are not environmentally sustainable no matter how clean each individual vehicle is.

Improved access is not only environmentally beneficial, but also has a social and economic element: it helps prevent communities breaking up, and it potentially frees greater resources for other things. It also includes groups who are easily excluded from the picture, such as the aged, the young and the disabled.

It's the economy

A government advisory body in the UK, the arcanely named Standing Advisory Committee on Trunk Road Assessment (Sactra), produced a little publicized but groundbreaking report in 1999. *Transport and the Economy* showed that there is no automatic economic or jobs benefit from improved transport. While the idea is not new, the Sactra report is the first by an official governmental body to demonstrate it. This means governments can no longer rationally claim that building roads will definitely improve the economy or provide additional jobs.

Building infrastructure has a number of well known negative environmental and social effects: for example, destroying habitats, splitting communities and encouraging greater use of roads, resulting in higher pollution and congestion costs. By decoupling roads and the economy, it is possible to argue that the negative effects of infrastructure construction need to be given far more weight. Over time, the decoupling of infrastructure and the economy should change thinking about transport planning in much the same way as thinking on energy was changed after energy had been decoupled from the economy. It could be argued that people would like a decoupling of transport and the economy so that they can avoid undertaking unwanted journeys.

The Sactra report, an extensive review by some of the most respected experts in the field over an extended period, highlights what some environmental economists have been saying for a number of years. A corollary to this report is that building roads to improve welfare can fail to have the desired effect once a full cost-benefit analysis has been made.

As the results of the officially endorsed view become better known, governments should start to assess each infrastructure building project on its individual merits, fully taking account of strategic and environmental impact assessments as well as cost-benefit analyses. Thus the first argument paralysing political will, that "roads are good for the economy", will disappear over time.

In countries with good freedom of information and a strong civil society, citizens' and taxpayers' groups will start to challenge the great expense of road-building. Citizens are increasingly willing to protest if they feel their money is being poorly spent, and the Sactra report is strong ammunition with which to challenge road-building.

The fuel price protests that shook Europe in September 2000 show people's unwillingness to put up with what they see as poor economic management. Thousands of truckers took to the streets and were supported by millions of citizens. Some environmentalists rejected the protests as ill-informed. Nevertheless, public support was based on the widespread perception that the level of fuel prices in Europe were too high because of unfair "rapacious" taxation on the part of governments.

Although the overall cost of motorized transport is certainly too low in Europe and elsewhere, levying taxes on fuels is a blunt instrument that discriminates against groups within society such as the poor and those living in rural areas, without good access to public transport, who need a car to access goods and services. Some governments have tried to argue that the level of fuel taxes was for environmental purposes. By contrast, citizens saw it as a revenue-raising enterprise, and claims that tax levels are unfair are to an extent justified.

A potentially fairer and more equitable approach to making transport pay its full environmental costs – if introduced together with measures such as improved public transport services – would be to lower fuel duty and to introduce more specific polluter-pays mechanisms, such as a kilometre charge for the use of roads.

There is now widespread acceptance of the principle that the economy can function more efficiently, and therefore contribute to greater overall welfare, if environmental costs are taken into consideration and the polluter or user pays for the damage s/he causes, so that society as a whole doesn't have to.

Reducing road-building efforts in the wake of the Sactra report is not only good in itself, avoiding the attendant problems; it can also free up resources for other projects, such as improving local public transport networks in both urban and rural areas, not to mention hospitals and schools. Such approaches are not only less expensive and more efficient than building large-scale infrastructure projects, but are also more equitable, providing greater access to goods and services and thereby improving quality of life and reducing the perceived need to use private cars.

The Swiss example

The experience of Switzerland shows the development of transport policies over time, presenting a salutary lesson to countries that have not yet made (and can therefore avoid) the mistakes of more "developed" countries. While each country has its specific issues, the Swiss case is worth noting as an example of a national transport policy that is moving towards sustainability. The Swiss example also indicates that environmentally "friendly" policies can be put into practice when citizens are both informed and involved in the decision-making process.

Transport policy has been much discussed in Switzerland for many years. As with all political decisions there, it has been subject to public votes and referenda. While this political system is often seen as conservative, slow and inflexible, it has developed a transport policy which, if not entirely sustainable, is much closer to sustainability than the policies of other countries.

The Swiss transport system is characterized by a high share of public transport modes with respect to both passengers and goods. That is quite surprising for a small country with many remote areas. There is a widespread belief that rail freight only makes sense over distances that would extend far beyond the borders of Switzerland. Nevertheless, railways have a share of more than 30% of tonne-kilometres in internal traffic, over twice the size of the rail freight share within the EU. The following maps the decisions taken in Swiss transport policy in general, and the approach followed in the freight transport sector in particular, all of which have been supported by the general public.

From the rail age through the road age towards the co-existence age

This could be the title of Swiss transport policy in the 20th century. As in many other countries, transport policy was dominated a century ago by railways. Transit traffic, which has always played an important role in Switzerland, benefited from the shortest, then new, railway link through the Alps (Gotthard). The Swiss Federal Railways were founded, and in the first half of the 20th century the railway network was entirely electrified. Railways had a near monopoly on transport, as use of

private cars and transport of goods by trucks were very limited.

The situation started to change in the 1950s, as transport volume on roads began to grow. The decision to build up a motorway network was a major contribution to the development of road transport. In 1958, 85% of the Swiss approved the construction of a road network of almost 1700 kilometres. Railways were neglected, with neither investment nor innovation being made. The emphasis was entirely on roads until the mid-1970s, and road transport grew dramatically.

The first oil crisis and the first negative impact of increasing road transport led to a change in thinking on transport. The government twice proposed fixing a modally balanced transport policy in the Constitution. These general attempts were unsuccessful, as they failed to be voted. Nevertheless, several concrete projects were able to realize the philosophy behind balancing transport modes. In several votes, a majority approved investments in the railway system and in the public transport system generally. This is an important lesson: the public was willing to support clear policies that brought a clear benefit.

In parallel, the public transport sector started to be more innovative, for example by introducing a comprehensive timetable with regular departure times and guaranteed services on every link. In almost all Swiss agglomerations, a fare community now exists that allows use of all means of public transport (bus, tram and trains) with a single ticket. In some cases commuters also benefit from subsidized transport passes within these areas. The very popular half-price pass is available at national level (almost 2 million Swiss, out of a population of 7 million, buy one each year).

All these urban and national passenger transport measures result in a comparably high share of public transport among commuters. The public transport carrot is supported by the stick of widespread demand management of parking spaces in city centres, where short-term parking is possible but daily parking is prohibitively expensive. Finally, residential areas are often protected by a lower speed limit of 30 km/hour. The overall effect is a system that is easy to use and affordable, and that provides access to daily needs. It is also less environmentally damaging and more efficient than previously.

A coherent freight transport policy

Swiss freight transport policy is further down the road to sustainability. The Gotthard tunnel opened to road vehicles in 1981, bringing a drastic increase in trucks passing through the Swiss Alps. In 1994, the Swiss agreed on an initiative to protect the sensitive Alpine region from damage caused by transit traffic, limiting the weight of trucks to 28 tonnes.

Experience showed that this was not sufficient to protect the Alpine region, as the number of vehicles has grown over time. Also, the EU was unhappy with the restriction as it caused lorries to detour through other sensitive Alpine areas in Austria and France. As a result, the recently adopted bilateral agreement between the EU and Switzerland requires Switzerland to change the weight limit to 40 tonnes by 2005.

In parallel, however, Switzerland will introduce a Heavy Vehicles Fee (HVF) from 2001. This is an innovation in reasonable and variable kilometre charging. The fee depends on the maximum permissible laden weight of the vehicle, the distance driven within Switzerland, and the vehicle's emissions (i.e. Euro environmental class). These elements together define the costs of a truck using Swiss roads. The HVF is therefore an excellent instrument for applying the polluter pays principle. It covers infrastructure costs, noise, health, accident costs, and damage caused to buildings. Every vehicle with a maximum laden weight of more then 3.5 tonnes is subjected to the fee. In the EU the bottom limit is fixed at 12 tonnes. The lower limit is more reasonable, being a better application of the polluter pays principle and avoiding any incentives to use a larger number of smaller vehicles.

Most importantly, the Swiss HVF is applicable on every road, not only on motorways. This again contradicts existing EU practice, but is sensible as other roads are a greater generator of external costs than motorways. Charging all roads avoids undesired traffic diversion from motorways to other networks.

While the EU does not implement this system, it has recognized the principle of fair payment for infrastructure use. Swiss transport policy seems to be in line with the EU's own stated goals of dealing with environmental pollution by making the polluter pay.

At the international level, aviation is the best current example of an environmental problem in transport that is not being dealt with. Here the key to the problem is not improving access to goods and services at local level, but rather making this exceptionally polluting mode of transport accountable for the damage it does to the environment.

The particular problem of aviation

While individual vehicles are becoming less polluting thanks to impressive technological improvements, the rate of pollution continues to increase. The problem is one of volume, with transport demand growing too fast for technological improvements to lessen overall emissions. Aviation, currently growing at a rate of around 6% per year, is a particularly good example.

Over the last four decades the volume of air travel has doubled every eight years, corresponding to an average growth rate 2.5 times that of world economic growth. The result is that aviation emissions form an increasing share of human-made greenhouse gas emissions.[1] This is not sustainable.

Air transport has become a serious environmental problem. It has local (noise), regional (air pollution) and global effects (GHG emissions and ozone depletion). All forms of pollution caused by aviation need to be addressed, but only aviation's contribution to global warming will be discussed here.

As long as aviation does not pay its true environmental costs, we will have a distorted and inefficient transport system with the wrong price signals being given and aviation being favoured over less polluting modes, even over shorter distances. For a number of years European environmental NGOs have called for the aviation sector to be treated equally with other transport modes, and for the abolition of the tax exemptions they enjoy at both European and international levels. There is currently a universal and complete exemption on fuel taxes for international flights, and in only two countries (the US and Norway) is the fuel used on domestic flights taxed. Norway's tax is environmentally based, while that of the US is revenue-raising. Norway tried to introduce a CO_2 tax on aviation fuel in early 1999, but it was withdrawn a few months later under pressure from the aviation industry.

Despite the available evidence that international aviation is the fastest growing and most polluting mode of transport, it is exempt from taxation on ticket sales as well as fuel. It has so far been exempted by governments from the emission reduction requirements of the Kyoto Protocol, which does not contain sector-specific targets. Under a business as usual scenario, with no measures being taken to reverse the trend, aviation emissions of CO_2 alone are expected to increase by around 3% per year between 1992 and 2015.

Recent developments in the level of knowledge concerning aviation's impact on the global atmosphere have encouraged both the International Civil Aviation Organisation (ICAO) and the EU to investigate market-based instruments for reducing its contribution to global warming. "Developed" countries, where 80% of flights happen, are required to reduce emissions of greenhouse gas pollutants by an average 5.2% by the Kyoto Protocol's commitment period, 2008-2012, and failing to deal with aviation emissions would place a larger burden on other sectors.

Ideally, ICAO would introduce a global instrument to assess and control this global problem. But ICAO is a slow-moving body characterized by long decision-making processes, and is largely dominated by industry concerns. So while ICAO is currently investigating a series of possible measures, for possible adoption in the second half of 2001, it seems unlikely that all 186 ICAO members will adopt strong and effective environmental measures.

For this reason, a coalition of European environmental NGOs argues the EU should be prepared to go it alone if ICAO fails to come up with anything meaningful in 2001. A European environmental aviation charge would be legally feasible and environmentally effective. With political will for such a move increasing in Europe (the European Parliament has given its overwhelming support to strong EU action on aviation emissions[2]), it is likely that citizens would welcome such an initiative, especially given the more local problems associated with aviation.

Whatever the final outcome, it is clear that there is increasing agreement that the international nature of aviation's pollution requires international solutions, and that these must include